A Summary of Current Program, 4/1/65

and Preliminary Report of Progress

for 4/1/64 to 3/31/65

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AGRICULTURAL ENGINEERING RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between April 1, 1964, and March 31, 1965. Current agricultural research findings are also published in the monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland.

UNITED STATES DEPARTMENT OF AGRICULTURE
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INTRODUCTION

Agricultural Engineering Research as used in this report is concerned with the applications of engineering principles to agricultural production and rural living. More specifically, it deals with the power, machines and structures required, and includes (a) development of new and improved equipment for the more effective mechanization of seedbed preparation, fertilization, planting, cultivation, pesticide application, harvesting and farm handling of crops, and studies of the more efficient use of such equipment; (b) development of more effective and lower cost buildings and equipment for the handling and sheltering of livestock, including research in functional requirements; for the handling and storing of farm commodities on the farm, and for farm living; (c) development of more effective methods and equipment for the mechanical preparation and conditioning of farm products for farm use or sale, including such testing and quality determination as needed to adequately evaluate research results, and (d) adaptation and development of methods and equipment for effective and economical farm and rural applications of electric energy, used as power, heat, light and other electromagnetic radiations for plant and animal production, farm processing and rural living.

The importance of Agricultural Engineering research to the nation's agriculture is shown by the fact that power, machines and structures with which it is concerned are essential facilities for every one of more than 3.5 million farms on which equipment and buildings valued at over 45 billion dollars are used to produce and handle about 600 million tons of crop and animal products each year. Also, the solutions of most plant and animal production problems are in part determined by the machines and structures available and likewise almost every new finding in soil, plant, or animal science research requires additional engineering research for its most effective implementation. As the relative cost of labor increases and the mechanization of agricultural operations progresses, engineering research becomes increasingly important. Since the close of World War II the annual man-hours of farm laborhave been reduced to one-half, from 17.4 billion to 8.4 billion, the number of tractors has doubled, from about 2.5 million to 5.1 million, and the percent of farms served by electric power lines has also doubled from about 48 to over 98. Each farm worker has available between 30 and 40 mechanical and electric horsepower. The investment per worker for land and other facilities, which is higher than for all manufacturing, averages over $25,000. For many commercial farms it is more than twice as great and for certain types of farms over large areas it is $100,000 or more.

The following examples are illustrative of research accomplishments for which the Agricultural Engineering Research Division (AERD) has had a major responsibility:

(1) Determining the effects of plow size and type on performance in different soil types and conditions; the effects of tire characteristics such as cord arrangement, tread design, rim width and diameter, and inflation pressure on the performance of traction tires on different soil types and field conditions; and the effects of methods of manufacture and steel specifications on the service of disks used on agricultural implements. The determinations are being used by the farm equipment industry and technical advisors to farmers as well as directly by farmers.

(2) Agricultural engineering research has made possible the effective ginning of the machine and rough hand-harvested seed cotton. The developments of this research program have been a primary factor in maintaining the competitive position of cotton.

(3) In cooperation with several State Experiment Stations, good progress has been made in mechanizing the harvesting and farm handling of several fruit crops, including cherries, blueberries, prunes, and dates. This is particularly true for tart cherries where labor requirements have been reduced by 75 percent and costs by 50 percent.

(4) Ventilation of livestock buildings--Research in cooperation with State Experiment Stations has obtained much needed basic data on the heat and moisture given off by cattle, hogs, and poultry, and on the influence of building environment on production and feed consumption. The heat and moisture dissipation data are considered basic design data for ventilation systems of poultry, dairy, and swine buildings. They appear in design handbooks including the 1965 Guide and Data Book of the American Society of Heating, Refrigeration, Ventilating, and Air Conditioning Engineers, and are used by makers of ventilating equipment, prefabricated buildings and package buildings as well as by specialists advising farmers on their own construction. Building improvements resulting from the above research have contributed to the substantial rise in efficiency of livestock production that has occurred during the past decade.

(5) Research on light traps for insects, pioneered by AERD, has developed this device as a very effective means for detection and estimation of insect infestation. This development has aided quarantine activities and the planning of chemical control operations. More than 700 electric traps are in use to determine emergence and migration of the pink bollworm moth in the Southwest and the European chafer in the Northeast and thus facilitate more efficient use of chemical controls. An additional 400-500 traps are used for detecting mosquito populations. An estimated 400-500 general purpose electric traps are in use to determine new infestations of economic insect pests. Special multipurpose traps are used at points of entry to detect foreign insects.

The first field scale test of light traps for insect control was initiated in a 113 square mile area in North Carolina in 1962. Here 366 traps of special design are used for catching tobacco hornworm moths. The results

of the 1962, 1963 and 1964 seasons have been very promising and indicated that hornworm moth populations in the tobacco can be reduced by use of electric insect traps when installed at a density of 3 per square mile over an area at least 12 miles in diameter.

However, in spite of the rapid and unprecedented progress in farm mechanization during recent years, many important field and farmstead operations are still not mechanized or are only inadequately mechanized. There are also many unsolved problems in the mechanical preparation and conditioning of farm products for farm storage and use, and for sale. There are many undeveloped opportunities for the more effective and extensive application of the different forms of electromagnetic energy and there is urgent need for the development of more effective and economic farm buildings for storing products, sheltering livestock, and farm family living.

Agricultural Engineering research is carried out by the Agricultural Engineering Research Division of the Agricultural Research Service of the U. S. Department of Agriculture, by nearly all of the State Experiment Stations, and by farm equipment manufacturers, manufacturers of building materials and prefabricated buildings, and to a limited extent by trade associations.

A characteristic of current Agricultural Engineering research is the relatively small program of the USDA and also of the State Experiment Stations in this field compared to that of public research in other fields of agriculture. This imbalance is serious because 80 percent or more of all agricultural research involves engineering, either during its conduct or during the application of its positive findings. Also as agriculture becomes more complex the need for expanded public agency research in agricultural engineering to determine for industry the fundamental principles and the basic requirements of the power, machinery and structures needed for an efficient agriculture become increasingly urgent.

In commenting on Balance among Phases of the U.S.D.A. Research Program in its report of April, 1965, the National Agricultural Research Advisory Committee stated, "Problems in agricultural research are constantly changing in relative importance necessitating a periodic review to maintain a proper balance. Two areas of research are of special concern to the Committee. It believes the current level of engineering research both on the part of the USDA and the State Experiment Stations is too low."

Thus, although there is need for the expansion of independent basic research in agricultural engineering, there is also need for a considerable expansion of agricultural engineering research cooperative and concurrent with other related agricultural research programs and also cooperative with industry whenever circumstances indicate the desirability of such cooperation. It should be noted that public agency research in agricultural engineering is complementary to and often cooperative with private research and not a competitive duplication of research by industry.

The Agricultural Engineering Research Division has 33 of its 159 professional workers located at the Beltsville Agricultural Research Center; 17 at 11 federal field stations, and 110 at 31 State Experiment Stations.

Of the 110 Department professional workers now at State Station locations, 28 are in 7 specialized Federal laboratories, such as the National Tillage Machinery Laboratory at Auburn, Ala. Most are working cooperatively with State-employed workers on mutually agreed problems that have both State and National significance. Much of the research is carried on by teams including both engineers and scientists trained in other disciplines.

The program at Beltsville includes leadership for work done in the field and research on problems of National interest. Basic research involving 28 engineers conducted at 16 locations, including Beltsville, deals with soil and equipment relationships, pesticides and fertilizers application, crop conditioning, cotton ginning, environmental requirements (including light) for livestock, electromagnetic radiation for seed and plant product treatment, insect attraction and destruction, and nondestructive determination of fat and lean on live animals. Most of the work at other locations is directed toward solution of specific problems.

The program of the Agricultural Engineering Research Division is reported under 14 Research Areas shown in the Table of Contents.

AREA NO. 1: SOIL - MACHINE RELATIONSHIPS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle chassis, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundmental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved response of crops and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; Athens, Georgia; State College, Mississippi; and East Lansing, Michigan. USDA personnel working on this project are stationed at Auburn, Alabama, and Ames, Iowa. Much of the work at the National Tillage Machinery Laboratory at Auburn is cooperative with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests and field observations.

The Federal scientific effort devoted to research in this area totals 10.0 professional man-years. Of this number 2.0 is devoted to traction and transport devices and soil reaction; 1.2 to the effect of tillage practices on plant growth; 1.6 to the measurement of soil physical properties; 2.0 to equipment mechanics; 1.0 to the effect of soil mechanics; 0.5 to methods of mathematical analysis; 1.1 to systems of equipment for conservation farming; and 0.6 for program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. These studies are concerned in the broadest sense with the development of theories, special devices, and laboratory and field tests to determine ways in which tractive and transport equipment, tillage tools and systems for their use might be improved.

Investigations are in progress on ways to develop and apply more efficient methods of soil manipulation that will produce improved soil physical conditions for seed emergence and optimum plant production; development and evaluation of systems of tillage which offer possibilities in reducing time, labor, or equipment to produce a crop; determination of fundamental and predictable relationships between external energy applications and soil breakdown and consolidation; exploration of techniques necessary for improvement of deteriorated soil structure and soil tilth; probing into possible ways that traction and flotation of farm machines might be improved to overcome the problems caused by compaction;and measurements of power

requirements, stresses and wear on tools and equipment as an aid to improved farming efficiency.

Many of these research investigations are cooperative with the Department. A total of 19.9 professional man-years per year of research effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Traction and Transport Devices and Soil Reaction.

1. This project is designed to determine and evaluate the effects of various construction, materials, and operational factors on the performance of tires and tracks when used for traction and for transport.

Data from tests planned to measure the effects of tire diameter on rear tractor tire performance were analyzed and results summarized in a paper presented at the annual meeting of American Society of Agricultural Engineers, June, 1964. Results show that there is a complicated inter-relationship between rim diameters, inflation pressure, tire deflection and tire loading. A mathematical analysis designed to separate the effect of the several factors shows that the individual effect of diameter alone may be either positive or negative but when measured by coefficient traction the greater load carrying capacity that comes with increased tire diameter definitely increases effectiveness.

Work on the cooperative project with the Bell Telephone Laboratories to study the traction capabilities of tracks on submerged soils has been completed. This required the development and construction of a versatile track test unit in addition to the actual test program. All tests were made in Lakeland sand as study showed it to be similar to soils on the Atlantic Continental Shelf. This study showed that the regular Waterways Experiment Station penetrometer using 1/2 in. projected area, the California Bearing Ratio penetrometer, and the Cohron Sheargraph were not sensitive to variations in this low strength submerged sand. However, a penetrometer using a modified cone with a projected area of 3 sq. in. adequately differentiated soil condition and was used for the study. Results show that if the cone index determined with this instrument is above 35, coefficient of traction will be about half what it is for the sand in a field condition. It has been found that soils on the Atlantic Continental Shelf are above this strength. It was found also that the coefficient of traction was higher for the narrower widths of track.

Tests made cooperatively with the U. S. Rubber Co., compared the performance of three experimental tires with that of two production tires in three soils and on concrete. The variations in the experimental tires were in tread design only. Results show that the performances were so nearly alike that tread wear, service life, road ability, economy in construction, or other factors should be used to determine the best tread design.

The Tractive and Transport Efficiency Committee of ASAE met at the NTML October 27, 1964, prior to the Off-Road-Locomotion Symposium sponsored by Auburn University and NTML. This committee met also March 11-12, 1965, at the Land Locomotion Laboratory, Warren (Detroit), Michigan. Work being done by Federal and State agencies and commercial interests was reviewed with the purpose of correlating the work where possible. It was indicated that this Laboratory is the only unit that is free to work on proposed problems in our field. Other units must work only on items within their companies interest or what they can sell to a group or agency. The committee is developing a bibliography of material on traction and transport and has a terminology subcommittee developing a dictionary so as to have a common language for people working in this field. The staff at the NTML is working closely with all phases of this committee's program.

B. Effect of Tillage Practices on Plant Growth

1. Minimum Tillage for Potatoes. The replicated plot work with primary tillage methods for potatoes was completed in the fall of 1963. Briefly summarized, the results of this study indicated that there were no advantages obtained with any of the primary tillage treatments tested as compared with planting potatoes in wheat stubble with no prior tillage. In fact, the highest average yield was obtained with no primary tillage.

2. In the soil-mixing study at Stoneville, Mississippi, large field plots of Tunica silty clay soil, a stratified clay over sand deposit, were deep-plowed or mixed with a ditcher in 1962. After one crop year the plots were in good physical condition for tests. Good stands and high yields of cotton on the deep-treated plots were significantly better than shallow tilled checks this year. The longevity of this treatment is being recorded.

3. Effect of the crop preceding, and the depth of seedbed preparation on peanut production, cooperative with Georgia, was continued. The area was prepared and planted to corn, cotton, soybeans, and winter rye grass. The results of these investigations from the last two years continued to indicate that the previous crop had greater influence on the yield than the tillage used.

4. Precision tillage (where the subsoil slot is placed precisely under the intended row of cotton)was found to be as effective applied in field capacity moisture soil as in drier soil as measured by plant response and yield at Shafter. Vibrating subsoil shanks used as precision tillage equipment were shown to be no more effective than rigid shanks in increasing cotton yield in certain soils. Cotton plant height and yield were shown to decrease as the soil compaction was increased. The yields were the same for all plots when precision tillage was used. Precision tillage 20 inches deep under the seed row was evaluated on irrigated and dryland Amarillo loam soil at Lubbock for the third year. No yield increase over conventional seedbed preparation was observed in the 1964 study. At stoneville for the third consecutive year, well-pulverized seedbeds resulting from secondary tillage with a disk harrow improved emergence and survival of cotton plants, but did not improve yields.

C. Measurement of Soil Physical Properties.

1. The work of this project is primarily basic laboratory studies but some field tests are conducted in Alabama and Georgia. Research is designed to develop functional relationships for tillage tool-soil systems that describe the reaction of soil to variations in tool geometry or manner of movement of the tool. These relationships are needed to design and to guide the operation of tillage machinery.

Equations of similitude with vertical chisels were extended to include effects of the depth/width ratio and the included leading apex angle of triangular chisels. Resistance to penetration of a cone penetrometer proved to be more effective in correcting for distortion in the model system than did shear with an annulus ring. Within a range from 14 to 180 degrees the leading apex angle had no consistent effect on model prediction. That is the change in the apex angle did not distort the prediction of the prototype performance from measurements made with the model. The depth/width ratio, to a maximum of three, did not materially affect model prediction. The relationship of draft and apex angle was not precisely established but it is not a linear one.

The deep plowing project was completed in 1964. Penetration resistance continued to be reduced most at the six inch depth by deep plowing. Clod size tended to be less in the eight inch deep fall plowed plots than in the eight inch deep spring plowed plots. Following are some of the conclusions from the investigations of this project: Compacted layers may be removed by deep plowing when soil measurements are made to determine the depth of compacted layers and used as a basis to set the plow. There is a residual effect of deep plowing which maintains a looser condition through the growing season in clay soils. Resistances in the plant line may be lowered by as much as 50 percent by deeper plowing when the compacted zone is removed. Clod sizes may be effectively reduced by harrowing moist soil before drying causes hardening. The repeated deep plowing by a plow which scours, gradually conditions soil so that the production of large clods is minimized.

2. A growth chamber has been completed at Auburn, Alabama, for making studies of the effect of soil physical conditions on root development and seedling emergence under controlled environment conditions. The interior chamber is 12 ft. long, 10 ft. wide and 7 ft. high. Density, aeration, moisture, temperature and chemical status interact to influence root development. The construction and adjustment of the growth chamber has been completed and initial plans made for root studies.

The characterization of soil resistance to deformation is being attempted in studies of soil cutting. The resistance to deformation should be a function of the deformation distance and different size cutters are used to vary deformation distance. Resistances due to soil friction and cutting are to be separated from soil resistance to deformation. A series of triangular chisels of different sizes is used to deform confined soil to

different amounts. Deformation of the soil is determined by measuring the location of buried markers before and after deformation. Soil is cut across a central smooth interface in a split sample box where markers can easily be found after disassembly of the box. Deformation in the direction of cutting is materially influenced by adhered soil bodies in an artificial soil. The percent lateral deformation (right angles to cutting areas) may be nearly linear as a function of distance from the axis.

The preparation of a comprehensive ARS Handbook "Soil Dynamics in Tillage and Traction" is in progress. Material included in the manuscript is being developed from a technical analysis of scattered and fragmentary information which is available. The broad scope of the analysis along with new ideas and concepts developed permits an orientation of soil dynamics with inter-related disciplines concerning machine design, soil physical conditions and plant growth. The manuscript should be completed in the next annual report year.

D. Equipment Mechanics.

1. Basic studies of full scale tools were made to determine the effect of design factors on performance. Studies of soil forces acting on single and multiple unit implements operating in various soil conditions were conducted. In a cooperative study with a manufacturer, it was found that even though there was some interaction between bottoms on a multibottom moldboard plow, the total forces on such an implement can be predicted from the forces measured on a single plow bottom.

In a study in cooperation with Bell Telephone Laboratories, Inc., the basic study on single-tines (chisels) performed in 1960 was extended to include straight surfaces in combinations of negative and positive rake angles and widths of 3-1/4, 5-1/4, and 7-1/4 in., at speeds from 25 to 200 ft. per minute. It was found that the draft force varied in proportion to speed, while the vertical force did not change appreciably. For the widths tested, the positively sloped surfaces did not exert enough vertical force to equal the upward force caused by the 1-1/4 in. wide center section having a negative rake angle.

A study, run cooperatively with another manufacturer, was made to compare the forces on a standard production moldboard plow bottom to those on a modified plow bottom having most of the inversion section of the moldboard replaced by two tapered rubber-covered rollers (a Hungarian system). No significant difference was found between the forces on the two plows in soil conditions where plowing is normally done. The modified plow did offer about 10 percent draft reduction in a very moist plastic clay soil with a sod cover that would not normally be plowed in the condition tested.

E. Methods of Mathematical Analysis.

1. To design or predict performance of tillage tools and traction devices, equations that represent the behavior of soil or of elements of soil-machine systems are required. The behavior can generally be classified as the relations between applied forces and resulting deformations. This project attempts to determine these relations by simultaneously measuring forces and deformations and empirically developing the equations.

An annulus ring simulates an element of a soil-traction device system. The element is composed of: (1) a unit area of the ring and (2) the volume of soil that lies beneath and reacts with the unit area of the ring. Work reported under this project last year showed that the tangential force on the unit area of a ring is uniquely related to the normal force on the area and the horizontal displacement of the area. This year different sized annuli were used to determine if the different annuli would give the same results when compared in a soil condition on a unit area basis. Different annuli did not give the same results although each soil-annulus combination produced its own unique relationship between tangential force, normal force and horizontal displacement.

Any annulus represents a finite area and the finite area influences the depth of subtended soil that responds to the annulus. Measurements were made which demonstrate that soil strength variation with depth affects a soil-annulus system. Therefore, the measured differences between different annuli may have resulted directly from soil strength variation with depth rather than directly from annuli size differences.

Failure criteria for soil itself were studied. Shear and compaction have been widely used but historical criteria equations, which geometrically represent lines or curves, can not describe possible interaction. Compaction can occur during shear and vice versa. Recently criteria equations for saturated soil have been developed that separate compaction and shear. Geometrically, these equations represent surfaces rather than curves and, therefore, can describe possible interactions. Work is planned to determine if shear and compaction failure in unsaturated soil can be represented by surfaces.

F. Systems of Equipment for Conservation Farming.

1. Studies were continued in Iowa on the use of herbicides to reduce or eliminate seedbed preparation. Overall spray applications of atrazine, simazine, and 2,4-D sprays were made in early spring on unplowed and spring plowed cornstalk ground. Secondary tillage treatments included disking and harrowing, disking, strip tillage with cultivator sweeps, strip tillage with a rototiller, and no secondary tillage. The control or check treatment to which all others were compared was conventional moldboard plowing, disking, and spike tooth harrowing. The yields, stand, and weed weight data collected show that on spring plowed land most of the secondary tillage was unnecessary.

Atrazine was the most successful chemical used. On unplowed cornstalk land, yields were lower than normal because of the high moisture conditions that persisted during the early growing season. None of the chemicals performed well enough to eliminate all mechanical cultivations. However, where atrazine was used, only one cultivation was required. Satisfactory stands were usually not obtained where no tillage was performed. A single disking or strip tillage over the old corn row to a depth of not more than two inches appears to be adequate to obtain satisfactory stands. These results indicate that corn can be successfully grown in Central Iowa with little or no seedbed preparation if adequate stands and weed control can be obtained.

Studies were continued on equipment and methods for preparing seedbeds and controlling weeds on ridge planted corn. Through the use of pre-plant applications of herbicides on contoured ridges that had been formed 12 years ago, it was possible to obtain almost complete control of runoff and erosion and to maintain a high level of stands and yields. Comparisons of growing continuous corn on ridges that were constructed each year and continuous corn grown in the conventional manner show that the two systems are equivalent where similar stand levels and weed control were obtained. Chemical weed control was somewhat more consistent than mechanical methods with the ridge planting system.

Studies were conducted on the effect of moldboard plows, disk harrows, spike tooth harrows on the soil density, clod size, and surface roughness. Results showed that the moldboard plow decreases the density of the soil plow layer by 25 to 35 percent. Subsequent disking and harrowing increases the soil density. The degree of compaction appears to depend on soil type as well as on moisture content. An examination of clod sizes ranging from 1/8 in. to three inches in 1/8-in. increments showed that the plow produced the largest clods and that subsequent operations caused only a minor change in the clod size distribution. Changes in surface roughness before and after tillage showed that the plow resulted in the roughest soil surface and that subsequent operations tended to smooth or level the soil surface. It appears that one disking and one harrowing would be adequate but that three diskings would usually result in a slightly smoother soil surface.

Studies with model moldboard plows were conducted to develop a functional relationship between measurable variables that would be useful for predicting the forces on full-size moldboard plows working in various soil types. These studies were conducted in small soil bins where the soil variables could be controlled and the forces on the tools could be accurately measured. Measurements were made of the soil strength properties and the draft forces on model moldboard plows operating at different speeds through various soils. The data were used to develop a functional relationship between dimensionless draft force terms and other dimensionless terms made up of the measurable variables. A functional relationship was developed for mathematically predicting draft forces on moldboard plows.

This relationship was found to be valid for model plows of a given configuration operating in soils exhibiting a rather wide range of soil strength values. In these model studies, real soils were used, and apparent cohesion was a dominant soil strength property. Test results indicate that the selection of apparent cohesion and the tangent of the angle of shear resistance are pertinent soil strength properties. Although it was not possible to determine the effects of apparent adhesion and the coefficient of soil to metal friction, it is believed that these factors are also important.

G. Foreign Research Under Public Law 480 Funds.

1. Research was completed after three years on a contract under PL 480 funds with the Agricultural Research Station, Beit Dagan, Israel. This research concerned tillage methods and implements for mountain farms. The report on this research gives quantitative values of soil movement with several tillage tools, and should be of value in the U.S. in managing tillage practices on sloping land. Following are some of the conclusions given in the report: (a) When plowing a hillside on the contour with a moldboard or disc plow through the whole range of slopes from -18 percent to +18 percent (the minus sign for casting the furrow downhill), the furrow depth decreases and the furrow width increases with increasing slope. The cross section area of the furrow slice,therefore, remains constant throughout the whole range of slopes. (b) The absolute value of the distance of soil shift (absolute value of distance of throw) caused by plowing on the contour is an inverse function of the slope through its whole range and is, therefore, a maximum at -18 percent and a minimum at +18 percent. However, its direction is downhill on negative and uphill on positive slopes. (c) A constant gradient of the slope can be maintained by uphill casting with a moldboard or disc plow and the effects of sheet erosion may be counteracted by this measure. Hillsides should be plowed on the contour with a reversible moldboard or disc plow, casting the furrow uphill. Downhill casting should be avoided completely. (This recommendation might be questioned for certain combinations of steep grades and deep surface soil, such as found in the Palouse area of eastern Washington). (d) An orchard disc harrow working on the contour causes only slight downhill movement on steep slopes (10 percent). No soil movement was observed on smaller slopes.

The report from Israel also contains some practical suggestions in the use of safety devices on tillage tools for stony land. Following are some of the conclusions given relating to safety: (a) The safety devices for stony lands should automatically return to their working position without the necessity to stop the tractor. Break-away devices which are not self returning should be restricted to land with few obstructions, and resetting should be possible by backing up or raising and lowering the power lift, without the necessity of getting off the tractor. (b) In soils with obstructions of soft limestone, heavy duty disc plows and disc harrows with 24-26 in. discs are suitable, provided that the quality of tillage is

acceptable. (c) Resilient tine chisel cultivators, similar to the model produced locally, are at present the most suitable implements for the deep cultivation of stony lands. For medium to shallow cultivation, a field cultivator with cushion springs or with spring release shanks, adapted specially for stony lands, may be used. (d) For plowing of stony lands with a moldboard plow, mounted plows, with individual, automatically returning trip beams, as produced by several Swedish manufacturers, may be used satisfactorily.

2. In October 1963, a three year research project contract under PL 480 funds was executed with the Institute of Agricultural Engineering, University of Bologna, Bologna, Italy. This research concerns the development of methods and equipment for breaking up cohesive clay soils to depths up to 36 in. Progress has been made with equipment and instrumentation for the tests, but there has been delay in obtaining a suitable field for the field work. A suitable field has been obtained and it is hoped that significant progress can be made with the field experiments during the summer of 1965.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Systems of Equipment for Conservation Farming.

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AREA NO. 2: PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The row spacing used on many crops is still that which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the past have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

The greatest need in cotton production is cost reduction. Seedbed preparation remains one of the costliest operations in production in many areas; and planting is plagued by the uncertainty of getting a stand and the urgency of timeliness and precision. Research has begun to develop optimum tillage systems in some areas but they need further development and extension into other soils and climates. Although some progress is being made, more basic knowledge of the micro-environmental requirements of the cotton seed is needed; and this needs to be translated into planting

equipment to give better precision in the control of seedbed physical conditions. Better control of the seedbed shape, size, spacing and seed position will also have a direct bearing on the economy of using new and more potent pesticides.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of applied engineering research on planting methods and means of applying fertilizer on various crops. Cooperative studies are in progress at 26 locations which are in the bounds of 13 states (Arizona, Florida, Georgia, Indiana, Louisiana, Maryland, Michigan, Nevada, New Mexico, Oklahoma, Tennessee, Texas and Washington). The professional staff members with their respective laboratory and engineering facilities are headquartered or operated at three locations: In the east at ARC, Beltsville, Maryland; in the southeast at Athens, Georgia; and in the southwest at Bushland, Texas. Forty-three field experiments were conducted cooperatively in 1964 with either State experiment stations, other ARS Divisions, or some commercial research units, which involved studies with 21 crops. Seventeen special machines were provided to put in seed and fertilizer placement experiments this season -- machines either solely or cooperatively designed and constructed by the Investigation Unit. Three new machines or new principles of study of previously designed special machines were provided by staff research engineers. Six publications or formal presentations were issued or made of this work as joint releases of these cooperative studies.

In the spring of 1958, cooperative endeavor was requested of ARS to determine effective means of removal of hazardous contamination to agricultural lands that may result from nuclear explosions, by use of farm and industrial equipment. This work is cooperative with SWC and is conducted under contract and funds of the Atomic Energy Commission.

The Federal scientific effort devoted to research in this area totals 9.0 professional man-years. Of this number 0.9 is devoted to fertilizer placement and distribution equipment; 0.1 to seed planting equipment; 0.4 to transplanting and fertilizing equipment; 1.9 to equipment for establishment of forages; 2.8 to cotton seedbed preparation, planting, and fertilizing equipment; 0.4 to vegetable planting equipment; 2.0 to decontamination of agricultural land; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Problems concerned with planting of the many sizes and shapes of seed of agricultural crops together with the introduction of fertilizers for use by these crops are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as

well as solid fertilizers. In both instances the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

Involved in these studies are design and testing of the several elements of machines together with investigations of the mechanics of seedling emergence. Basic research is also underway in an effort to determine the environmental conditions that are necessary for maximum emergence and how these conditions may be controlled or altered with mechanical equipment. Companion to these overall studies are limited testing, improvement and development of equipment for aerial applications of seed and fertilizer.

A total of 11.7 man-years per year of research effort is devoted to this work.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Fertilizer Placement and Distribution Equipment.

1. Eighteen experiments on the establishment of field crops and vegetables were put in cooperatively with various State, Federal and commercial research units. Some typical results or trends shown of the field experiments of field crops or vegetables are: Winter wheat yields in cooperative field experiments with Michigan averaged 51 bu/acre, while check plots with conventional openers with fertilizer in contact with seed averaged 35 bu/acre. These findings conform to the results in two other states (as reported last year) and the separate seed-fertilizer opener developed by the project for close drilled seed has proved quite successful on the special machines for research. One of the major implement companies has issued a seed-fertilizer opener patterned after our development. Although it is quite successful for experimental and slow speeds (up to 2 mph) for field use, there is need for further development to meet the present day high speed planting requirements (up to 5 mph).

B. Equipment for Establishment of Forages.

1. Sixteen experiments on the establishment and production of pastures and haylands were put in cooperatively with State and Federal research units. Some typical results that show response or definite trends from new planting or application methods in the various studies are: In a first year experiment with methods of establishing Coastal bermudagrass in the southeast, superior stands resulted when a small amount of water was placed with each sprig that had half of the fertilizer side placed in two continuous bands at time of sprigging. The first six weeks after sprigging were high in temperatures, and no precipitation. The stands and final ground coverage were better than irrigated treatments and this treatment with no herbicides equalled the other half of the plot treated with herbicides. This was a cooperative study with the AE and Agronomy Departments of the University of Georgia, and the SWC station at Watkinsville. In interseeding Birdsfoot

trefoil in bluegrass sod in Maryland, experimental seed-fertilizer openers were able to establish a six-month stand which average about 25 plants per running foot. The plots interseeded by commercial seed-fertilizer sod openers had a zero stand after six months.

Cooperative studies on planting methods and means of applying fertilizer on forage crops in the southwest area were conducted in four states (Texas, New Mexico, Oklahoma and Louisiana). The studies involved various cultural methods on grass seeding, interseeding grass on rangeland and on abandoned cropland, and sand dune stabilization. In regard to grass establishment as affected by soil compaction, forage yields went down as the soil strength went up. Better seedling emergence and establishment were obtained by late seedings (June). After two seasons of interseeding side-oats grama grass in abandoned farmland, shallow seeding late in the spring gave highest survival of seedlings. One half inch seeding depth was superior to one inch depth (1963 season only). May and June seedings gave highest seedling survival (1963 & 1964). In sand dune stabilization (Oklahoma) the fertilization of existing plant species appears to be promising in solving sand dune problems within reasonable economical limits. Vegetative mulches to establish vegetative cover indicate superiority to chemical mulches, but both are prohibitive (costwise) at present day values. Growing mulch in place (sorghums or small grains) so far has not been feasible.

2. A contract was signed in June, 1964, whereby the New Mexico Agricultural Experiment Station is to conduct 3-1/2 years of research for the Department on the design and development of range seeding equipment for use with brush eradication equipment in the arid Southwest. The primary objective of the research is to modify existing equipment or to develop equipment that will accomplish the following four operations in one pass over the land: eradicate undesirable shrubs, provide a firm seedbed, plant seed effectively, and windrow plowed-up brush over the planted strip.

Three major types of equipment have been investigated: a rootplow, a seeder to firm the seedbed behind the rootplow and effectively plant grass seeds, and windrowing equipment to place plowed-up brush over the planted strip to give shade and wind protection to emerging plants. A rootplow with an 8-ft. horizontal blade, commercially available, operating at a depth of about 10 in., proved effective in eradicating creosotebush and tarbush. No modification of the rootplow was necessary. A range seeder, also commercially available, was attached behind the rootplow and seeded four rows spaced one foot apart, making a 3-ft. wide seeded strip. After some minor modifications, the range seeder satisfactorily provided a firm seedbed and planted seed effectively.

Several types of equipment were tried for windrowing the plowed-up brush over the planted seed, but without entire success. When a grader blade was operated at from about 40° to 60° with respect to the rootplow blade, portions of the brush became caught between the grader blade and the ground.

When a modified blade, 14-ft. long, was attached behind the rootplow, no practicable angle could be found at which the brush would move satisfactorily across the face of the blade. A hay windrower attachment, normally used behind a 7-ft. mower cutter bar, was tried for moving the brush over the seeded strip, but which tended to catch and drag the brush instead of moving it laterally over the seeded row. A side delivery hay rake with rotating tines was tested back of the rootplow for moving the brush over the seeded row. Observation of this rake indicated that the principle of operation may be suitable if the rake wheels are shielded. Additional studies of brush windrowing equipment will be made.

C. Cotton Seedbed Preparation, Planting and Fertilizing Equipment.

1. In crop residue disposal studies at Stoneville, design changes incorporated in a new shredder-tiller residue disposal machine permitted faster field speeds and maintained disposal efficiency by changing rotor rotation and modifying tiller shields. An experimental complete-disposal device assembled in 1963 was field tested and dismantled for extensive design changes.

2. In seedbed preparation tests at Shafter, a minimized tillage system was compared to a normal system. Third-year results show no difference in yield with a system that requires only 30 percent of the horsepower hours of the normal system. A profile of the soil strength shows that three different conditions have been created in the minimized system: (a) high surface strength for tractor traffic, (b) low surface strength in the irrigation furrow and (c) low strength to 26 in. deep in the rooting zone.

3. Field tests of planting equipment on a Bosket very fine sandy loam at Stoneville indicate a definite relationship of soil conditions and soil treatment at the time of planting to cotton plant emergence. Soil conditions altered by some planting equipment resulted in slower emergence, poorer stands, and delayed maturity, but did not affect total harvested yields. In comparative tests at Lubbock, the precision-depth planter developed last year was superior in earliness and uniformity of plant emergence. Press wheels on the covering soil provided a slight increase in maximum seed zone temperature and reduced moisture loss; however, the higher soil strength produced by pressing the covering soil decreased cotton seedling emergence. Vibrating covering soil attachments did not increase seedling emergence or yield of cotton.

Plant population and spacing-plots at Lubbock were planted flat in rows spaced 5, 10, 20, 30 and 40 in. apart and on 40-in. spaced beds using two rows per bed spaced 4, 8, 12, and 16 in. apart. Populations ranged from 20,000 to 500,000 per acre. Marked differences in earliness and difference in yield were observed due to the row spacing and population treatments. Varying plant population and hill spacing on a Bosket very fine sandy loam at Stoneville resulted in pronounced differences in plant characteristics and seed cotton yield in a very dry growing season. Hills spaced 36 in.

apart and containing from two to five plants per hill produced three of the five top yields in a total of 16 treatments. Hills 12 in. apart with one and two plants per hill accounted for the other two top yields.

D. Vegetable Planting and Fertilizing Equipment (including Potatoes).

1. After three seasons of cooperative fertilizer placement studies in Florida on four vegetables, only one vegetable crop gave no response. For example, on peppers, the use of a single band, or one 2-1/2 in. on each side of plant row and 2-1/2 in. below at time of transplanting increased yields of about 31 percent. However, efficient use of fertilizers on green beans and cucumbers responded to the use of high-low fertilizer positions (half of fertilizer 2-1/2 x 2-1/2; other half, same side width, but 6 in. deep). Special drill FJ 44 and special transplanter F 75 were used with the field experiments.

Cooperative studies with planting and fertilizing field crops and vegetable crops in the southwest area were conducted at six locations which are in the bounds of three states (Texas, Nevada, Arizona). The studies involved micro-nutrient studies with lister planting of cotton; macro-nutrient studies with cotton and potatoes; and fertilizer placement studies with potatoes. Four seasons of potato fertilizer placement experiments under irrigation practices in Arizona indicated that continuous bands 4 in. on each side and 2 in. below seed piece gave superior production. Yield increase ranged from 7 to 19 percent over other placement positions, which included the common placement of bands two inches on each side and on level of seed piece.

E. Decontamination of Agricultural Land.

1. In the physical decontamination of agricultural lands from radioactive fallout, the primary activity was the development of a deep plowing arrangement for removing the contaminated ground surface and placing it deep in the soil.

A large moldboard plow, Post Brothers Model PB-142, capable of plowing furrows three feet deep, was evaluated for its effectiveness in burying simulated radioactive fallout by conducting two tests - one in the spring and one in the fall.

The production model plow was modified by installing a scraper blade on the plow so that the surface layer of soil containing the contamination could be scraped from the surface and dropped into the bottom of the furrow. This modification was essential to obtain an effective burial. For the conditions studied, it was found that by means of glass microspheres tagged with radioactive gold 198 distributed on the surface, 95 percent of the radioactivity could be buried over 21 in. below the surface. For various soil conditions, other modifications were found helpful in the operation and performance of the plow. These modifications consisted of:

depth indicator, level indicator, independent hydraulic control for vertical position of wheels, landside retainer, plowed soil deflector panel and relocation of rear support shoe. Scraping depths of 0, 1, 2, 3 and 4 in. were studied. It was found that scraping depths of three in. or more were needed as depths of 0, 1 and 2 in. left activity on the surface.

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AREA NO. 3: CROP PEST CONTROL TECHNIQUES AND EQUIPMENT *

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the methods which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control, and it is time consuming and costly. It is believed that with sprayers and dusters now used, often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provides sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio, on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa and Columbia, Missouri.

* Except electric, which is in Area 11.

Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington Stations, on low growing crops. Pest control equipment research for certain crops is conducted: for cotton at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; Lubbock, Texas; and (particularly for boll weevil control) at State College, Mississippi; for vegetable crops at Forest Grove, Oregon; and for brush control at Mayaguez, Puerto Rico and College Station, Texas.

The Federal scientific effort devoted to research in this area totals 19.0 professional man-years per year. Of this number 2.0 is devoted to basic studies in aerosols and spray formations; 1.0 to soil fumigation; 3.4 to insect control in grain; 2.0 to weed control in corn and soybeans; 3.1 to pest control in cotton; 0.8 to insect and disease control by ground equipment in vegetables and other low-growing crops; 1.8 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.3 to aerial spray equipment for forest insect control; 2.4 to brush control equipment and methods; and 1.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack our economic crops are in progress at the several Agricultural Experiment Stations. Much of this work is cooperative with the Department.

These studies are involved in the complicated objectives of furthering the efficiency and the means for better control of insects, plant diseases, nematodes and weed problems through application of engineering knowledge on the use of aerial and ground chemical applicators for liquids and dusts, flame cultivators and mechanical devices for soil manipulation and soil fumigation.

A total of 2.7 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Studies in Aerosols and Spray Formation

1. Theoretical and experimental studies on the basic transport, spreading, and distribution processes for fine particles suspended in turbulent fluids were continued at the Pioneering Research Laboratory on Physics of Fine Particles at Wooster, Ohio, in cooperation with the Ohio Station. A laboratory-built instrument (fluoroscanner) is in use for continuous scanning of fluorescent-particle-traced aerosol deposits on solid surfaces. Signals generated by the fluoroscanner during the scan of deposition test surfaces are tape-recorded and later subjected to computer analysis. A spectral density analyzer was constructed during the year and represents one mode

of analysis being applied to the tape-recorded signals. Deposition spectra are being measured and will be compared with models developed on the basis of stochastic theory to determine whether any consistently meaningful relationships exist between the deposit structure and the fluid turbulence which takes part in its generation. As another aspect of this study, a hot-wire anomometer system is being assembled for measurement of experimental turbulence parameters.

A Flying-Spot Particle Analyzer system was installed by AE at Wooster, Ohio, during the year. The instrument performs counting and sizing measurements on fine particle systems through the medium of photographs or photomicrographs in the form of 35 mm negative films. Work has been under way on the development of sampling and photographic techniques appropriate to the instrument for both liquid droplets and solid particles. Special paper, film, and liquid collection media have been used for droplets. In cooperative work with the USDA Soft Wheat Laboratory at Wooster, Ohio, studies of starch granule systems have been made with the aid of the Particle Analyzer. In cooperation with the Ohio Station, extensive measurements have been made of electron micrographs of Bentonite clay which are now under analysis.

B. Soil Fumigation

1. Experimental equipment was used to apply soil treatments, in cooperation with the Ohio Station, for development of a control of Verticillium wilt in strawberries, potatoes, eggplant, okra, tomatoes, and various other vegetables. Methods of controlling damping-off in nursery plantings, radish clubroot and control of populations of various nematode species in fruit and vegetable plantings were included in the experiments. The application of chloropicrin by equipment which sealed the fumigant under a polyethylene cover was fairly effective in controlling Verticillium in several vegetable plantings. This material is too expensive at this time for use on many crops. In-the-planter-row application equipment which placed a fungicide-insecticide formulation in the onion seed row at planting,produced some increases of over 50 percent in stands and yield increases over 20 percent. Cherry trees planted in some treatments made in 1957 and 1960 continue to show much better growth than check trees and lesion and pin nematode populations are lower in the treated areas.

Soil treatments were applied in Ohio for the study of residue remaining in the soil. In muck soil plots treated with the same chemicals for the past eight years, those receiving bromine compounds now show 68 ppm of bromine in one case and 56 ppm in another. The check shows 32 ppm. Onions will not grow in 68 ppm and yields of potatoes are greatly reduced. Yields of beets, spinach, and lettuce are also reduced. Celery and carrot yields are increased, probably because of root-knot control. At 56 ppm, onion yield has gradually been reduced and the crop failed in 1964. Yields of potatoes, beets, and spinach are also reduced. Celery, carrots, and radishes show no yield effect.

Liquid mulches were applied in Ohio to several vegetable plantings. The use of a zero pressure wheel to smooth the soil surface preparatory to mulch application produced better results than drag equipment. Seedlings penetrated the wax and asphalt applications better than a latex application. An application rate of about 400-450 gallons per acre seemed desirable for most ordinary vegetable plantings. Under the conditions of these experiments, soil temperatures under the black mulches were raised two to three degrees above those under unmulched surfaces and moisture contents were raised one to two percent for a few days. This apparently produced better seed germination and earlier maturity in a number of vegetables. This is particularly important in growing crops for sale on the early markets.

C. Insect Control in Grain

1. Insecticide granules were applied for control of Northern corn root worm in cooperation with the Ohio Station, with equipment developed or adapted for small plot treatment. A fluted-type feeder gave extremely accurate application rates of a large number of different granular materials used. In one experiment using 12 different insecticides only one, heptachlor, was significantly better than the untreated check, yielding 18 bushels of corn per acre more than the check. No significant differences were found among the roots damaged and the number of plants that were lodged.

In investigations in cooperation with the Iowa Station, the major emphasis of the program was the screening of new insecticides, development of systemic insecticide control, and development of combined control of the European corn borer and corn rootworms. The results of these studies indicate that several experimental compounds may be as effective for borer control as presently recommended compounds. American Cyanamid 47470 was shown to be the most effective compound for systemic control of corn borers, however, Niagara 10242 demonstrated some activity. Experiments in 1964 show it is possible to combine the control of first-generation corn borers and corn rootworm larvae with one application of insecticide.

2. Ultrasonics are being investigated in Georgia as a possible means of controlling insects on southern grain crops without chemicals. Field work has been concentrated on repelling corn earworm moths, while laboratory work has been devoted primarily to destruction of eggs and larvae. Ultrasonics used in the laboratory did not reduce armyworm or earworm egg viability within an exposure time of five minutes or less. However, ultrasonics killed the first instar larvae of either the armyworm or earworm in less than 15 seconds.

Seeds of corn were oriented in Georgia at the time of planting to determine if the foliage and ears could be oriented and, if so, would the orientation effect insecticidal application for insect control. These tests did not show any orientation of the ears or foliage, with the ears growing about the same in each direction. Yields were slightly higher from the oriented rows. Insect damage was not significantly different between the oriented and unoriented rows, receiving the same insecticide treatments.

3. DDT was further evaluated in Georgia for its effectiveness in controlling corn earworms in sweet corn. Three plots were treated by recommended procedures with 2 lbs.DDT/A. One plot was treated every day, another plot was treated every second day, and the other plot was treated every third day. The plot receiving a treatment every day resulted in 66 percent worm free ears. The plot treated every second and third day had 50 and 53 percent worm free ears, respectively. Effective earworm control was not obtained.

A study was made in Georgia for determining residues and insect control in sweet corn when applying an insecticide in the form of a dust, liquid and granule. The dust was applied through nozzles positively charged with 13,200 volts of electricity, negatively charged at the same voltage, and uncharged. The emulsifiable concentrate liquid was applied by spraying and with a brush applicator. Spraying gave the best insect control, while the brush applicator was next. Granular form was decidedly the poorest. The brush applied more insecticide on the target area (ear tips) than the spray, and used 1.6 lbs. DDT/A against 2 lbs. DDT/A applied with the spray. Dust from positively charged nozzles gave the highest dust deposition.

D. Weed Control in Corn and Soybeans.

1. Several methods of applying preemergence chemicals for weed control in corn were used in investigations cooperative with the Iowa Station. Mixing granular and liquid formulations of atrazine, 2,4-D, and Randox T into the soil at planting time with rotary hoes, drag harrows or wire wheels did not improve the effectiveness of the compounds. With atrazine and simazine liquid preemergence applications gave better weed control than granular formulations. Granular and liquid formulations of 2,4-D and Randox T applied at planting time were equally effective. None of the preemergence treatments gave full season weed control, and one additional mechanical cultivation was required for band treatments.

Studies on equipment, techniques, and chemicals for directional postemergence sprays in corn were continued in Iowa. Results were erratic but did show that this practice has possibilities as a "salvage" operation. Studies on weed control practices for narrow-row corn indicate the need for little or no change in mechanical or chemical methods. Earlier soil shading with narrow rows resulted in improved weed control. Timely mechanical cultivations gave better weed control in narrow-row corn than most chemicals.

Early spring applications of atrazine and simazine in Iowa on plowed soil successfully controlled weeds in corn throughout the growing season without secondary tillage or cultivations. Similar applications on unplowed cornstalk ground were nearly as successful but required one mechanical cultivation.

Field studies were made in cooperation with the Missouri Station to evaluate different methods for directed applications of dalapon (1 & 2 lbs./A) for weed control in corn. Directed applications were made that varied from no leaf protection to maximum leaf protection provided by tying the leaves to the corn stalk. Three different applicators (a special shield leaf lifter, a wire leaf lifter and a special directed nozzle) were used in the study. Applications were made to corn under weed-free conditions so corn damage from contact with the dalapon could be evaluated. No significant corn damage was noted for any of the treatments. This is the first year of a three-year study where no damage occurred. This is thought to be due to the absence of rainfall after application this year. Additional studies will be made under both weed-free and weedy conditions. A field study was made to determine if incorporation of amiben (1, 2, 3 and 6 lbs./A) would allow its use for weed control in corn. However, incorporation did not reduce the damage to the corn. All treatments resulted in lower corn yield than for the cultivated check treatments.

Field studies were continued in Missouri to determine the effectiveness of 8, 10, 12, 14 and 16-inch band applications, sprayed over the rows, of 2,4-D, simazine and atrazine for weed control in corn. In each case, the amount of active ingredient for the area actually covered was the same, resulting in a saving of chemical for the narrower bands. The middles between the rows received one cultivation, and it was more difficult to cultivate the plots that were treated with the narrower bands of spray. No significant difference in corn yield was noted for any of the band applications.

Field studies were also continued in Missouri to determine the effectiveness of 8, 10, 12, 14 and 16-inch band applications of amiben and NaPCP for weed control in soybeans. These studies were conducted in a manner similar to those in corn, but with the different chemicals. Results were similar as no significant difference in soybean yield was noted for any of the band applications.

The direction of movement of the herbicides in soil was studied during the band applications in corn and soybeans in Missouri. In the crop year 1963, under dry soil conditions, weed control was effective over a wider area than the applied band. In 1964, control was limited to the actual area under the band. This would denote that there is greater lateral movement of the herbicide under dry soil conditions, however, this study will be continued in order to establish conclusive results.

2. Field studies were continued in cooperation with the Missouri Station to compare the effectiveness of 10, 6.6 and 3.3 percent concentrations of granular amiben (3 lbs./A) for weed control in soybeans. Applying more granules while maintaining the same acid equivalent application rate did not result in better weed control or increase soybean yields. In some cases, the higher concentrations, i.e., 10 and 6.6 percent, resulted in

better weed control and soybean yields. More granules which result in a greater distribution per unit area did not increase weed control when amiben is applied under field conditions.

Initial field studies were made in Missouri to determine the effectiveness of depths of incorporation of two herbicides used for weed control in soybeans. Incorporation of amiben (1, 2, 3 and 6 lbs./A) and trifluralin (1 lb./A) to depths of 0-, 1/2- and 1-inch with a power rotary cultivator did not result in increased weed control or soybean yields. No combination of herbicide and incorporation depth resulted in any significant better weed control than when the herbicide was not incorporated.

Studies were also made in Missouri to determine if soil moisture had an effect on weed control when amiben (0 and 2 lbs./A) was incorporated for weed control in soybeans. No correlation between weed control and soil moisture was indicated by weed control regardless of incorporation.

Field studies were continued in Missouri to compare the effectiveness of four methods of shallow (above the seed) incorporations of three pre-emergence herbicides for weed control in soybeans. The rotary hoe, Atkins Phelps Mix-A-Product, power rotary cultivator and Gandy Ro-Wheel were used to incorporate amiben (1 and 2 lbs./A) and trifluralin (1 lb./A). In most cases the shallow incorporation gave less control of early grass over no incorporation and did not result in any significant increase in soybean yield or overall better weed control. Very erratic results occurred due to the difficulty in maintaining a uniform depth of incorporation for all equipment except the rotary hoe.

E. Pest Control Equipment for Cotton

1. Nozzle wear studies were revised at Auburn to determine the effects of orifice size and pressure on wear, and the effects of cross winds on spray patterns. After spraying diuron (DW) for 30 hours at 40 psi, the increase in discharge was 13.3 percent for a brass nozzle applying 0.336 gpm as compared to 9.1 percent for a nozzle applying 1.012 gpm. (Wear was a more serious problem with the smaller nozzle.) The increase in discharge after spraying diuron (DW) for 30 hours at 40 psi was 13.3. percent as compared to 6.9 percent after spraying at 20 psi. Cross winds of 10 mph caused distortion and shifting of spray pattern. Greater distortion occurred when operating at 20 psi than 40 psi.

The development of automatic controls for chemical placement in connection with planting and for other preharvest operations was begun at Stoneville, Mississippi. A two-row experimental machine was designed and evaluated for automatically hilldropping cottonseed and applying precisely-sized spots of agricultural chemicals at specified locations in and around the hill of cotton. Pneumatic, electrical and mechanical energy were used to operate the various components of the machine. An automatic chopper for weed control between hills of cotton was also developed as a research

tool. Controls of this type permit the precision placement of seed, mechanical operations, and several chemicals in specific locations with respect to each other. The first year's experiments gave promising results.

Weed control in skip-row cotton poses a greater lay-by problem than solid cotton. A high and wide (HAW) machine was designed for cultivation and chemical applications in the skip-row cotton in Mississippi. It performed satisfactorily in cotton up to six feet tall, maintaining a weed control program until harvest time. It was equally effective in younger cotton. Deficiencies encountered were difficult turning and inadequate horsepower from the 26 h.p. engine for spraying and cultivating the 120-inch swath. A mixture of EPTC and diuron applied subsurface with this machine gave better lay-by weed control than conventional lay-by treatments. Shallow tillage after this chemical application extended the effectiveness of late-season control.

2. Chemical weed control equipment studies included basic and applied research on soil incorporation and subsurface application of chemicals. Techniques for rapidly and accurately measuring the distribution of pesticides placed in the soil were improved upon in Mississippi and California. The techniques are the same but the equipment used is slightly different. Basic work on power-driven incorporators in California continued to provide data on operating characteristics. Data indicates that mixing efficiency increases with rotor diameter and with relative velocity of the rotor to forward speed. Power requirements increased with relative velocity and with smaller soil "bites". Energy requirements for 8, 12, and 16-inch rotors were the same when other factors remained constant.

Soil incorporation studies were conducted in Alabama to determine the effects of incorporation on three different pre-emergence chemicals and to evaluate incorporating tools and depth of incorporation. Trifluralin was incorporated with five different tools. Weed counts showed no difference in weed control with different tools. Incorporating trifluralin from one inch to five inches deep did not affect weed control nor the yields of cotton. Soil incorporated trifluralin had only six percent as many weeds as surface applied trifluralin. Soil incorporated CIPC had 45 percent as many weeds as the surface applied CIPC. Diuron, incorporated, when compared with diuron, surface-applied, showed no difference in weed control.

At Lubbock, Texas, band incorporation with a row wheel and blade improved the weed control action of five pre-emergence herbicides -- diuron, Treflan, Prometyrne, Dacthal 75W and Herban. Incorporation of broadcast application of herbicides gave full-season control in narrow-row cotton. Pre-emergence chemicals gave more satisfactory weed control when applied to 40-in. row cotton planted on beds than when applied to cotton planted in the lister furrow.

Preliminary work was begun in Mississippi to develop equipment for precision placement of post-emergence subsurface herbicides in heavy clay soils. In exploratory tests, solid-stream nozzles positioned above ground level behind eight-inch disk coulters were compared with knife injectors using EPTC. The coulter arrangement proved to be unsatisfactory. However, control with knife injectors on each side of the crop and a directed spray of DMA and a surfactant in the drill area gave excellent weed control. The knife injectors were attached to the same applicator as the DMA nozzles. One year's results justify intensive efforts next season.

Further investigations were made on the triband concept of weed control with special emphasis on the Stoneville, Mississippi, blade applicator and a newly-designed knife-injector applicator. Minor modifications also were made on the planting units to improve performance. Evaluation trials again were conducted on sandy loam and silty clay loam soils. Satisfactory results were obtained on the sandy loam with the Stoneville blade, whereas the knife-injector applicator performed best on the silty clay loam.

Several nematocide placement tests in California indicated the effectiveness is greatly increased when combined with precision tillage (where the subsoil slot is placed precisely under the intended row of cotton) either in the same operation or a following operation. Consistently higher yields were obtained when the nematocide was released at the bottom of the subsoil shank or 20 to 24 inches deep.

3. In the area of boll weevil control, studies on mechanical methods of destroying fallen cotton squares were continued in cooperation with ENT at State College, Mississippi. An improved model of the flail machine was built and tested to determine its efficiency in square destruction and its effectiveness in boll weevil control.

Tests were made in two isolated spots in Florida. When five machine treatments were made in 22 days, the infestation reached a maximum of 10.2 percent in an eight week period compared to 46 percent ten days earlier in the check. Pickup efficiency was 84.5 percent. At the other location, infestation did not reach damaging numbers, but it was lower in the treated plots. At State College, migration masked the overall effects of the early treatments.

In tests to improve the drill area pickup efficiency, cup-type brushes in conjunction with an air blast gave 85 percent efficiency in the drill. The killing efficiency of the machine was 96.3 percent on the immature weevils which passed through the flail units.

F. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops

1. Five series of comparative tests for control of Cercospora leaf spot on sugar beets were made in cooperation with the Ohio Station, using boom and nozzle-type hydraulic sprayers. In a timing and interval study, the fungicide applications were spaced at 10, 15, and 20 day intervals with number of applications ranging from three to seven. The untreated check plots were virtually defoliated in late August following a short rainy period and, though these beets grew new leaves, their sugar content was reduced. The sprayed plots decreased in disease count as the number of applications were increased. The yield in gross sugar per acre was greatest with the 10-day schedule using six spray applications. In an experiment comparing effectiveness of a series of copper compounds, all were effective in disease control with little significant difference between compounds. In a third experiment, five experimental fungicides were compared with maneb and an untreated check. One compound TRTH (triphenyl tin hydroxide) applied at 2 pounds per acre was most effective in disease control and gave highest gross yield of sugar per acre. In a fourth experiment, a series of maneb formulations were applied with different zinc compounds as supplements. The results were inconclusive. The use of zinc as an additive to maneb seems to add very little to the effectiveness of maneb used alone. In a comparison to four oils with tribasic copper, the results were inconclusive.

A series of experiments were conducted in Ohio with an air-blast sprayer for control of Cercospora leaf spot on sugar beets. The sprayer was an adjustable turntable type with capacity of 33,000 cfm and 80 to 90 miles per hour air velocity. The swath width was 50 ft. Comparative applications of copper fungicide were made at 40, 20 and 10 gallons per acre rates with 300 and 60 psi for each rate. Disease control and yield data were taken. Determinations were also made of swath pattern of the copper fungicide spray deposited across the swath for the purpose of correlating with disease control and yield. The swath pattern for 40 gallon per acre rate at 300 psi gave a heavier spray deposit at a distance from the machine than for the other tests. This was due to the nozzle arrangement and the use of a large jet nozzle at the top of the manifold. There was no significant difference between 300 and 60 psi with the 20-gallon per acre rate. The 20-gallon applications gave the highest yields in tons of beets and gross sugar. At the 10 gallon per acre rate, 60 psi showed higher deposit of copper and also higher yields of beets and gross sugar than the 300 psi. The deposit pattern of sprays with air sprayers is changed or distorted by wind conditions at the time of application. The pattern can be changed and sometimes improved by adjusting the air outlet or changing position of nozzles on the outlet manifold.

G. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. Extensive spray application tests were made in Oregon with a Bell D-1 helicopter in cooperation with ENT. The effect of boom length and location, height of flight and speed of application on the shape of spray pattern and swath width, were investigated. The shorter 26-ft. boom gave a swath width of about 40 ft. when the application height was from five to eight feet. Increasing the boom width to 48 ft. increased the swath width by a distance of about the increase in boom length. For the two boom positions tested, there was no appreciable difference in pattern shape or swath width due to boom location. Increasing the height of flight to 20 to 25 ft. compared with five to eight feet increased the swath width about five feet for the shorter boom, and about 12 ft. for the longer boom. The speed of flight made no appreciable difference in the swath width. These tests were made with a uniform nozzle arrangement. However, the variation in deposit across the swath indicate the need of additional tests with a nonuniform nozzle arrangement to obtain a reasonable uniform deposit rate.

Spray pattern tests were conducted in Oregon using a Pawnee PA-25-235 airplane with modified wing tips. The modification consisted of removing the taper of the wings and squaring the ends. A nonuniform nozzle arrangement was used which produced a reasonably uniform deposit across the treated swath. On the basis of these tests an application elevation of 10 ft. and a swath spacing of 65 ft. was recommended for pesticide applications to low growing crops with this airplane.

Two spray applications were made to field plots of corn in Oregon with a Bell 47 D-1 helicopter to determine the effect of speed on spray penetration and rate of distribution. The speeds used were 30 and 57 mph. The height of the helicopter skids above the crop was from three to five feet. A 26-foot boom was used resulting in a swath width of about 39 ft. The mean recovery rates of spray as measured from sampling plates in the open were 8.9 gpa at 30 mph and 5.6 gpa at 57 mph. Almost 50 percent of the top leaf areas had deposits greater than five gpa for the 30 mph application speed compared to 19 percent for the 57 mph speed. About 86 percent of the underleaf sampling areas received 0 to 1.0 gpa deposit at the 30 mph speed compared to 62 percent for the 57 mph application speed.

H. Aerial Spray Equipment for Forest Insect Control

1. In spray distribution tests with the TBM (torpedo bomber) airplane, which were made at Beltsville, Maryland, in cooperation with the FS, a long underwing spray boom did not produce an appreciably wider swath at deposit levels generally used in forest spraying than did a shorter trailing edge boom. From the equipment operation standpoint the short boom on the trailing edge of the wing is to be preferred over the longer underwing boom.

A series of test flights were made at Beltsville to secure drop spectrum samples for measurement of the atomization of water sprays. A Piper PA18A at 80 mph was used with T8010 nozzles directed forward and down 45° to the thrust line of the plane and at 25 psi spray pressure. These nozzles are the ones currently recommended for atomization of 150-160 microns mass median diameter with oil sprays. An average of the data from five flights showed an mmd of 300 microns - about twice that of oil sprays. The difference was greater than expected and may be caused by the higher evaporation rate of water spray as compared to oil. It is expected that with additional tests a factor can be developed to allow conversion of D-max to mmd similar to that previously worked out for oil sprays.

Investigations by other workers have shown that electrostatic charging of dusts results in more effective deposition. The behavior of electrostatically charged spray drops was studied at Beltsville with respect to the atomization, distribution and foliage coverage of the spray. A rotary type laboratory spray apparatus was devised to charge the drops in a water spray as it was atomized. The charge could be made either positive or negative. The range in drop size was much narrower in a charged spray than in uncharged spray thus providing some degree of control of spray drop size. The charged spray cloud expanded as it left the apparatus. Apparently like-charged bodies were repelling each other. This action should produce a more uniform distribution of spray. The presence of a charge increased the amount of spray deposited on foliage from observations when charged spray was released above a small potted tree that was electrically grounded. A set of four spray charging devices have been designed for mounting on an airplane for further studies of use of this type of equipment.

I. Equipment for Brush Defoliation.

1. Work is underway in Puerto Rico and Texas in cooperation with CR on equipment and techniques for applying herbicides to tropical and subtropical forest areas. This work is being done for the Department of Defense. In the engineering work in Puerto Rico, three items of equipment have been developed and constructed for use in studying problems of spray application for brush defoliation: (a) equipment and procedures for applying herbicides to individual trees; (b) cableway with its spray cart and drive gear to study the factors affecting spray distribution throughout a multi-storied forest cover; and (c) weather station to measure temperature, humidity, precipitation, wind velocity and wind direction at the cableway site.

The equipment developed for spraying individual trees consists of a 50-ft. mast equipped with a spray boom. The boom has two 10-ft. sections, hinged at the top so that they can be folded along the mast when it is being raised through a tree. The boom is equipped with 12 nozzles graduated in size to give equal spray coverage over the entire area. Coverage of

the circular area is accomplished by rotating the mast 180° in a fixed interval of time. Spray is delivered to the boom by air pressure from a small portable compressor or air tanks.

The cableway is located in mountainous terrain east of Mayaguez. The cableway is supported, at the upper end, by two 35-foot tubular aluminum towers; and, at the lower end, by two 120-foot towers. These towers were installed by the local power company by the use of a helicopter. The distribution patterns of spray solutions through a tall, dense tropical forest, can be determined by the use of the cableway spray cart. The area will allow comparisons of penetration of sprays applied from aircraft to that applied by the cart.

The automatic data-logging weather station will be used in conjunction with the cableway sprayer. The station consists of a recording console, 17 sensing elements and a clock. The station was constructed by one of our engineers in Georgia and was flown to Puerto Rico and installed. The sensing elements for air and dew-point temperatures, wind velocity and wind direction are located at approximately 40 ft., 25 ft., and 1 ft. above ground level. The machine is constructed to punch out the recorded points continuously or at specified intervals from each five minutes up to each hour.

In Texas, in order to study the factors which effect the atomization of aerially-applied spray, a small low speed wind tunnel was constructed which provides air speeds of 50 to 140 mph. This tunnel will be used in laboratory studies of droplet formation and particle size regulation and air streams. Also, sampling techniques and equipment for measuring the distribution and penetration of materials on foliage in the field are being developed. Spray penetration sampling probes have been devised for holding sampling surfaces in dense vegetation. Samples of aerially-applied sprays were collected on stainless steel plates, mylar sheets, poster paper cards and mylar-covered labels. Preliminary samples collected on mylar sheets just above the foliage and five ft. deep in the foliage of Maccartney rose plants, have indicated that less than 10 percent of the aerially-applied spray penetrates to the five ft. depth.

To facilitate laboratory and greenhouse evaluation of herbicides on woody plants, a laboratory sprayer was designed and constructed in Texas, to give precise spray applications. This sprayer will accommodate plants up to four ft. in height. The plants rest on a stationary slatted floor and the spray is delivered from an overhead cart which runs the length of the table. This unit will be used for herbicidal applications in evaluation studies, for studying spray deposits on single plants and for developing spray distribution sampling techniques.

J. Foreign Research Under Public Law 480 Funds.

1. A three-year research contract under PL 480 funds with the Agricultural Research Station, Beit Dagan, Israel was executed in September 1964 to improve the penetration of insecticide sprays into the dense foliage of citrus trees. Most of the first six months have been spent in assembling and constructing equipment and apparatus necessary to the project.

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AREA 4: CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; Davis and Riverside, California; in cooperation with the respective State Experiment Stations. Equipment for cotton harvesting is under study at State College and Stoneville, Mississippi; Auburn, Alabama; Lubbock, Texas; and Shafter, California; in cooperation with USDA Cotton Ginning Laboratories and the respective Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Research on mechanical coffee harvesting has been initiated in cooperation with the Hawaii Experiment Station. Development of new techniques for harvesting forage is underway at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Georgia Experiment Station. Research on forage seed harvesting is underway at Corvallis, Oregon, in cooperation with the Oregon Experiment Station, farmers, and industry. Long fiber crops harvesting research at Belle Glade, Florida, is cooperative with the Everglades State Branch Experiment Station. Research on oilseeds and peanut harvesting equipment and methods is

cooperative with the Experiment Stations at Stillwater, Oklahoma (castor beans); Bogalusa, Louisiana (tung nut); and Holland, Virginia (peanuts). Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota. Equipment and methods for harvesting sugarcane are under study at Houma, Louisiana, in cooperation with the American Sugar Cane League; and in Belle Glade, Florida, in cooperation with the Florida Experiment Station. Tobacco harvesting research is conducted cooperatively with the Experiment Station at Lexington, Kentucky.

A contract with the University of Sao Paulo, Brazil, on mechanization of sugarcane production has been terminated due to lack of funds and personnel.

A 3-year contract was initiated at Louisiana State University for research on mechanically removing tops and leaf trash from sugarcane.

The Federal engineering effort devoted to research in this area totals 27.4 professional man-years. Of this number 4.0 is devoted to citrus; 4.4 to cotton; 5.5 to deciduous fruit; 1.5 to forage; 1.5 to forage seed; 1.5 to long fiber crops; 3.3 to oilseeds and peanuts; 2.0 to potatoes; 1.0 to sugarcane; 2.0 to tobacco and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Most of the state agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of the many economic crops which make up the total national agricultural production. Much of this research effort is cooperative with the Department.

Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Current research is concerned with the diverse problems involved with these specific crops: All small grains, including rice and field corn; cotton, peanuts, castor beans, and safflower; citrus, apples, peaches, olives, apricots, cherries, prunes, cranberries, coffee, grapes and pecans, green-cut forages, hay and seed crops; cabbage, lettuce, asparagus, tomatoes, Irish potatoes, sweet potatoes; blueberries, peas and sweet corn; tobacco; and sugarcane.

During the course of these engineering investigations close cooperation is maintained with research scientists who have responsibilities for making improvements to these crops. This activity is most important in order to have machines and systems that are compatible with the new developments.

A total of 44.2 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Citrus Harvesting Equipment

1. Harvesting citrus. The rapidly decreasing availability of suitable domestic labor for picking citrus and the termination of the off-shore labor and bracero programs have created a serious need for improved methods and equipment for harvesting citrus fruits.

In Florida, time of harvest trials with the tree shaker and catch frame harvest method continued in Valencia, Hamlin, and Pineapple oranges and Marsh grapefruit. A new tree shaker was designed and built which increased fruit removal. Another catch frame and shaker were constructed to match the previously built equipment to form a complete harvesting system. Tentative work rates and harvest cost data were established and this system is ready for commercial use when the need arises. The effects of limb size, hanger length, shaker frequency, and amplitude on fruit removal and stem retention were studied and data used in the tree shaker design.

A comprehensive fruit quality study was undertaken and results are not yet complete. Contract research was initiated on pruning for mechanical harvesting and use of chemical looseners to improve fruit removal. The compound, iodoacetic acid, showed considerable promise in loosening Hamlin and Pineapple oranges, thus reducing shaking time and attached stems.

The oscillating air blast harvesting trials were continued on a limited basis. The main problem is evaluation of tree damage and this has not been evaluated as yet by the horticulturists. The FMC-2 prototype air harvester is undergoing tests to determine optimum ground speed and air oscillation rates. Air volume and velocity were increased over last year's model. Fruit quality data with this method of harvesting are also being accumulated.

A number of tree wall pruning plots were put in (both young and old trees) for picking trials with both the ladder and bag method and picking platforms. The project has worked with a number of manufacturers and inventors trying to develop new ideas and equipment for citrus harvesting. Our fruit blocks and facilities have been made available for test work on numerous occasions.

In California, the effect of direct current electric power through citrus trees on causing abscission of the fruit is being investigated. Voltages of 6 to 120 are being used. The natural potential of trees is being determined. Much information on flow of nutrients through the tree is being obtained and this research is very promising.

An inexpensive man-positioning device has been designed and constructed and also looks promising. It is self-propelled and the movement is based both on linear and curvilinear cylindrical coordinates. A pulsating vertical air flow harvesting unit has been designed and constructed and will be tested. Two mass removal devices (one using oscillating tines, the other

rotating stripping tines) were constructed and tested. From 85 to 99 percent of the fruit was removed. However, 10 to 25 percent of the fruit was split. A vacuum twist unit for removing individual oranges was made and moved into the tree on a staggered grid pattern. Removal rates of 55 to 85 percent were obtained. In an attempt to reduce the distance of fall and thereby reduce the damage to the fruit in falling through the tree from a mass removal method, an intermediate catching device was developed and tested. This collecting device consists of a series of half-cylindrical troughs mounted parallel. These were cantilevered on coil springs to permit deflection so as to slide by the limbs upon penetrating the canopy of the tree. The troughs are inclined to permit the fruit to roll to the rear. For tests with oranges, this collecting device caught an average of 85 percent of the fruit with a range for the tests from 70 to 100 percent. The perferred mounting arrangement would be to have the troughs in two horizontal planes with the lower troughs beneath the spaces between the upper troughs.

Several methods of sensing devices were investigated. Spectral analysis of the reflectance of fruit, leaves, and bark revealed a ratio of approximately 10:1 between the relative reflectance of ripe oranges and leaves at a wavelength of 670mu. An experimental detector was constructed which utilized a long tube to limit the field of view from which light was reflected into a phototube. It was designed to limit the field to one orange at a distance of 25 feet from the tree. Optical filters with a peak wavelength of 657mu and 685mu were used individually to measure the reflected light at the two wavelengths. Both wavelengths were near the range found to be optimum for differentiating between ripe oranges and leaves. It was shown that fruit against a background of leaves could be detected at distances up to 25 feet when adequate light was present. Fruit on the perimeter of the tree on the side exposed to sunlight was adequately lighted. Fruit back in the tree and that on the shaded side was more difficult to detect. An artificial light source could be used to overcome this deficiency.

Several models of clippers were designed for single clipping. One model was field tested on Lisbon lemons and commercially tested on Eureka lemons. The stem cut was excellent and close to the button without cutting the button. Picking rate, using the test models, was felt to be lower than that of other previously developed single clip clippers.

Studies were initiated to determine the exact location of the fruit in the tree. For a 15 foot high Valencia orange tree, 89 percent of the fruit was in the zone from 2 to 12 feet above ground and 92 percent was within 3 feet of the mean radius of the exterior of the canopy at the respective fruit height.

B. Cotton Harvesting Equipment

1. The topping and vertical trimming test was continued at Stoneville for the third year. Topping rank-growing Stoneville 7A cotton plants on three different dates (July 20, August 5, and August 20) and trimming lateral branches just as they began to lap in the row middle (July 24) had no

effect on seed cotton yield lint grade, staple length, or picking efficiency. There was slightly less foreign matter in the machine-harvested seed cotton and lint from the topped and laterally-trimmed plots than from the untreated plants although no differences were obtained among the topped and trimmed treatments. Boll rot loss was reduced slightly by early topping (July 20) in an area where the average boll rot loss was less than 5 percent. Although plant lodging was not a problem in this area in 1964, it was observed that plants in the topped plots were more erect.

2. Sources of trash contamination during the mechanical harvesting operation were identified by the process of eliminating the major contributing factors before harvesting. Based on 3-year's data from this test at Auburn, the following conclusions have been reached: Ground trash is not a source of contamination. The picker, whether "clean" or "dirty," is not a source of contamination. Boll bracts constitute a large portion of the fine trash, indicating that a bractless cotton would be desirable for mechanical harvesting. Leaf trash constitutes about 20 percent of the total trash, even in well-defoliated cotton. Burs constituted an average of 50 percent of the total trash but varied greatly from year to year, depending upon deterioration of burs before harvesting.

3. A study of plant characteristics for mechanical picking at Stoneville included six widely different cotton varieties. More trash was harvested with Stoneville 7A, and the Delta Smooth Leaf variety had less trash in the ginned lint; however, there was no significant difference in lint grade and staple length. Delfos 9169 had the highest yield and picker efficiency, but there was no significant difference in the yield of Delfos 9169, Stoneville 7A, D & PL Smoothleaf, and Lankart 57. Yields and picking efficiencies were higher than usual and preharvest losses were very low as a result of excellent growing and harvesting conditions in 1964.

A technique utilizing a pendulum was developed at Auburn for measuring picking energy required to remove cotton from bolls. Strain gage equipment was used for similar measurements at Stoneville. These tests are designed to give cotton breeders a better criteria for evaluating the picking characteristics of cotton. For seven varieties having a moderate to low range in storm resistance, total field loss (including preharvest weather loss) decreased as picking energy increased at Auburn. This apparently does not hold true over wider extremes of storm resistance because of storm losses. Similar tests at Stoneville with the six varieties with widely diverse storm-resistant characteristics showed a relationship between the average peak force involved in removing a lock of cotton from the boll, the carpel angle of the boll, and picker efficiency. Lankart 57, a storm-resistant variety, required the most force for removal with an average of 162 grams, while Stoneville 7A, a typical open-boll variety, required an average of only 70.7 grams.

There was no interaction of picker drum height and plant population on picker efficiency. As drum height varied from 1 to 4 inches, the picker efficiency remained constant and was the same for plant populations of 10,000, 20,000,

40,000, 60,000 80,000, and 100,000 plants per acre. There was a definite decrease in harvested yield at populations greater than 60,000 plants per acre.

Picker efficiency was not affected by different skip-row patterns. The increase in harvested yield over the solid planted cotton at Auburn was 25 percent for the plant-two-and-skip-two pattern and 21 percent for the two-and-one pattern.

4. A 3-year study comparing the fiber qualities and spinning performance of cotton harvested with three types of spindle cotton pickers and by hand was completed at Stoneville. Results showed (1) no differences in lint grade between types of picker; (2) one-half grade increase in lint grade for hand harvesting compared with mechanical harvesting; (3) more short fibers in handpicked than machine-picked cotton, probably because of somewhat selective picking by the mechanical pickers; (4) no differences in fiber strength between handpicked and machine-picked cotton; (5) lower foreign matter in lint from handpicked cotton, which was reflected in lower picker and card waste in manufacturing; (6) little difference in spinning performance between handpicked and machine-picked cotton except in yarn strength and ends down; and (7) lower ends down at the 90 percent statistical level for one type spindle. This work has been completed and published.

5. Equipment for laboratory studies of picker performance was improved at Auburn and Stoneville. A mechanism for pulling the stalk-carrying trolley through the picking unit at synchronized speeds with the picker head, was designed and installed at Stoneville. A second glass pressure plate was built for the rear drum of the laboratory picker to facilitate the use of highspeed movie cameras on both drums of the picker. A series of highspeed movies was then taken of the picking action as stalks of open cotton passed through the picking unit. Improvements in highspeed photography techniques were suggested in preliminary trials. The movies gave additional emphasis to possibilities of removing trash within the picker head before it becomes entangled with the seed cotton.

The following information was obtained with the laboratory model cotton picker at Auburn: Boll exposure or picking time ranging from .16 seconds to .28 seconds did not affect spindle efficiency. The spindle efficiency for fluffy bolls was 95 percent compared with 90 percent for weathered bolls and 65 percent for knotty bolls.

The effect of spindle speed on spindle efficiency varied with boll type. For fluffy bolls, efficiency increased as the speed increased from 700 to 2,300 r.p.m., remained constant between 2,300 to 3,900 r.p.m., and decreased slightly at 4,700 r.p.m. Picking efficiency of knotty bolls increased linearly as spindle speed increased from 700 to 3,900 r.p.m. Picking efficiency of fluffy bolls was not affected as spindle spacing varied from 1-5/16 to 1-13/16 inches but decreased significantly as spacing was increased another 1/4 to 2-1/16 inches. For knotty bolls, the efficiency decreased

significantly for each one-fourth inch increase in spacing. The position at which the bolls entered the spindles also affected efficiency. Greatest efficiency was obtained when the boll was centered among four spindles. Poorest efficiency occurred when the spindle was centered on a boll. Spindles from the bottom three rows of a picker which had picked 150 bales had a picking efficiency about 5 percent lower than that of new spindles. The respective barb wear was 20, 15, 10, 5, and 3 percent for the first, second, third, fourth, and fifth barbs from the spindle tip. The remaining nine barbs showed no evidence of wear.

6. In a comparison of types of mechanical harvesters at Auburn, the flexible roll stripper had an efficiency of 98.6 percent as compared to 90.6 percent for the spindle picker. Due to the lower grade of the stripped cotton, the gross value of the harvested lint from four bales harvested in an alternate two-row comparison was the same for both machines.

7. Research on stripper-type harvesters at Lubbock indicated that burr extractors on the harvester may be feasible when used in combination with the USDA green boll separator. The broadcast cotton harvester designed by the project was improved by minor modifications, and its performance in narrow-row stormproof cotton was satisfactory.

8. In field storage and handling work at Lubbock, burr cotton was run through extractor-feeders, baled in the gin press, and then stored outside on pavement. One bale was removed and ginned in March, July, September, and December. Fiber deterioration had begun after 1-year's exposure and 12.92 inches of rainfall. Strength, length, and grade had decreased and the cavitoma reading increased in the December 31 ginning.

A preliminary investigation of field transport equipment was begun at Lubbock, looking toward more efficient handling in the field and unloading at the gin. A bottom dumping basket was used to determine the maximum density burr cotton that would fall from a basket or trailer under its own weight. The maximum density established in these tests was in the range of 9.0 to 10.5 lbs. per cubic foot.

C. Deciduous Fruit Harvesting Equipment

1. Harvesting grapes. About 225,000 tons of Concord grapes are produced each year in the States of New York, Michigan, Washington, Arkansas, Pennsylvania, and Ohio. Conventional harvesting and handling methods are expensive and cause considerable damage to the raw product. Research showed that grapes could be harvested with hand-held shakers and bunch grapes handled in pallet boxes. A report on the bulk handling studies and a grape box pick-up machine was published. This line project is being closed out June 1965.

2. Harvesting clingstone peaches and apricots. Hand labor for harvesting tender flesh fruits is scarce and may not be available in the near future. Previous research has shown it is feasible to mechanically harvest cling

peaches and apricots. Last year the mechanical properties of clingstone and freestone peaches, apricots, pears, and apples were studied. Pears can withstand a large compression force relative to the other fruit and, therefore, present the least problem of bruising of fruit in the bottom of bulk containers. Apricots, particularly very mature ones, are bruised by a relatively small compression force and, therefore, are more subject to bruising in bulk bins. Pears have a relatively large yield deformation, especially when compared to apples. This indicates that, when fruit is placed in a confined space (for example, a box for fresh shipment) and then deformed (as when the lid is applied to the box) apples are much more likely to be bruised than pears. Apricots and peaches have a much lower stiffness than either apples or pears, and the low stiffness results in a low natural frequency when the fruit is in containers. This low natural frequency often results in excessive movement and associated bruising of top fruit during transit, since they frequency correspond with the natural frequencies of transport vehicles. Therefore, pears and apples are less likely than either peaches or apricots to present problems on injury to the top fruit in containers. Studies showed that apples are more susceptible to impact bruises than peaches or apricots. Maturity affects mechanical properties of fruit and, therefore, time of harvest is important.

3. Harvesting dates. Dates grow on palm trees which are 30 to 50 feet high and it has become almost impossible to find workers to handpick fruit from these tall trees. Engineering help was given to growers and others in constructing mechanical harvesting equipment designed after the equipment and methods developed on this project. About 12 million pounds of fruit (one-third of total crop) was harvested mechanically this season. It appears that this will be increased to at least two-thirds of the crop next year. The bunch-cutting method of harvest will be the major method used. This project is being terminated May, 1965.

4. Field grading apples. Growers store millions of bushels of apples "orchard run." This means that many hundreds of thousands of bushels of undergrade fruit are stored in CA or regular storage and then sorted out and sent to cider mills or other low return outlets. A mobile field grader composed of a receiving belt, two eliminator sections, a sorting roller and a bulk bin filler was designed, constructed, and given preliminary tests. Results indicate thousands of dollards could be saved. The unit is being redesigned and will be given extensive tests and a report prepared.

5. Harvesting apples. Apples bruise easily and must be handled with care when harvested for fresh market. This type of picking is difficult, time consuming, and it is becoming difficult to recruit labor. Techniques and machines which will make it easier and less costly to harvest apples for fresh market are needed. Three sizes of trees (standard, semidwarf, and dwarf) were picked by the same picker without the use of any picking aids other than the conventional ladder and picking bag. The only apparent variables were tree size and planting arrangement. Compared to the rate obtained in standard trees, a 20.5 percent increase occurred in semidwarf trees and an increase of 17.0 percent resulted when picking dwarf trees in

a hedgerow planting. In an effort to further increase picking rates on hedgerow plantings of semi and dwarf trees a self-propelled unit is being constructed. Support for two pickers as well as a fruit conveying system has been provided. The unit will allow two pickers to pick continuously while being transported past the hedgerow of fruit.

6. Over 40 percent of the apples produced in the United States are now processed. Growers only receive $.80 to $1 per bushel for apples and profits are small. Present picking costs of $.20 to $.25 per bushel need to be reduced. The McIntosh and Spy apples which were shaker harvested and stored for 6 months were graded and compared to handpicked fruit. The results indicated as in previous work that processing apples can be harvested with tree shakers. However, more research is needed to determine details of holding times, handling methods, etc. This work will be continued in cooperation with a commercial processing company. The feasibility of using an endless air mat belt catching frame was investigated. A model was built to test the principle of dropping fruit onto a rotating air mat which would catch the fruit and subsequently convey it to the discharge end of a catching frame. Operation over level terrain appears practical, but additional trials with a full-scale prototype operating in various conditions are needed. Shake harvesting trials were performed on standard size trees of Golden Delicious, Red Delicious, and Winesap apples. The extent of fruit damage and type of separation were noted. Shake harvesting of Golden Delicious fruits does not appear feasible even for processing outlets since almost 42 percent of those removed by shaking had incurred some type of skin break. Red Delicious and Winesap apples destined for processing outlets have a much higher shake harvest potential.

7. Harvesting blueberries. Cultivated blueberries are grown commercially in the Midatlantic States, Great Lakes area, and the Pacific Northwest. Although this project has developed equipment and methods which greatly reduce the cost of harvesting and packing blueberries, costs are still rather high. A continuous-type blueberry harvester should reduce picking costs even further. Consulting service was given to several companies who are trying to develop a continuous-type harvester using the principle developed on this project. Progress has been slow and a commercial unit is not in sight. The second year of a 3-year study of the effect of mechanical picking on yields was made. Results show the yield per bunch is lowered but not significantly. Last year over 50 percent of the Michigan blueberry crop was harvested mechanically.

8. Harvesting cherries. Last year over one-half of the gross returns of tart cherries which were harvested by hand were paid to workers. These workers are becoming increasingly hard to recruit, a situation existing in all cherry-producing areas. The purpose of this research is to reduce harvest costs and labor requirements through mechanization and at the same time maintain quality of the fruit. Commercial harvesting equipment was studied and 32 changes in design were suggested in order to improve reliability of the equipment and to reduce bruising. Manufacturers are incorporating all changes in their 1966 equipment. The results of the 1964 study of

electric sorters were published and as a result the 1965 units were modified. We again studied units in ten separate plants and a report will be made available. The units have been improved to the extent that cost of sorting is lower than hand sorting and the sorting efficiency satisfactory. A destemmer was designed in cooperation with a commercial company and five units constructed. It, along with three other available destemmers, were evaluated. The experimental unit did a satisfactory job and had a per ton cost of from one-third to one-sixth less than the other units. It will be improved and tested for one more season before being put on the market for sale to processors. The study of cushioning materials was completed and a report published discussing available cushioning materials--their advantages and disadvantages. This report has had wide demand by manufacturers, growers, processors, and other researchers. A study of bruising showed that rebruising is serious and often occurs at receiving stations and the processing plants. Rebruising can result in soft cherries. A cherry hydrocooler was designed, constructed, and tested. This unit cooled cherries from 70° F. to 40° F. at a rate of 1.5 tons per hour. Further research is needed to determine whether hydro-cooling is desirable.

A study of physical and thermal properties of cherries was initiated. Measurements of density and specific heat were made for a wide range of cherry sizes and soluble solids. Results showed average density for the whole cherry to be 1.05 gm./c.c. and specific heat .88; for the flesh, density 1.04 and specific heat .91. These studies will be continued and a comprehensive report on cherry properties published.

9. Harvesting prunes. Although research on this project has led to the adoption of mechanical harvesting in the Sacramento Valley, prunes are still harvested by hand in the Santa Clara Valley where prunes fall to the ground as they mature over a month period. Tests to determine fruit removal as affected by shaking trees at the trunk in more than one direction were conducted in two orchards of different age and structure to obtain tree variation effects. One orchard was approximately 10 years old with many low flexible hangers; the other about 40 years old and representative of older trees with no low hanger and small hangers on secondary wood. The trees were first shaken in one direction, then a second shake was applied in the same direction or at 30, 45, 60, or 90 degrees from the original direction. Limb shaking and circular translation at the trunk were also compared. The results indicate a definite advantage in applying the shaking force at more than one direction with those approaching 90 degrees being most effective. Circular translation was somewhat more effective than the one direction shake but much less effective than the two directions 90 degrees apart. The removal of fruit by limb shaking was equivalent to or greater than any of the trunk shaking procedures.

10. Bark damage. Thousands of trees are now being harvested with tree shakers. Any break in the bark is an opening for disease and insects and, therefore, bark damage must be prevented. A new pad was developed for the use on shakers for cherry trees. This corregated surface, sponge rubber backed pad eliminated all bark damage for cherry trees. The new experimental

C-clamp with five prongs on each face was tested and limbs could be shaken at up to 65 degree angle without slippage. The 10 small punctures in the limb did not seem to hurt the tree but it now looks like this type of a clamp will not be necessary.

A test of bark strength as related to soil and bark moisture conditions was conducted on prune-orchard plots of four different irrigation treatments. Bark strength, soil moisture, and bark moisture were taken at 7- to 10-day intervals for a period from July 22 to September 16. An analysis of the bark strength shows that, in all three plots irrigated after June 15, a reduction in bark strength occurred around the end of July; whereas the non-irrigated plot did not exhibit this reduction but remained approximately constant. Therefore, the bark strength was affected by moisture conditions early in the season during the period of tree growth, but there was very little difference at the time that harvest commenced.

Tests of bark strength as related to tree age were conducted in two orchards; one with a tree age span of 4 to 23 years and the other from 6 to 17 years. In one orchard, bark strength was lowest for 6-year-old trees (225 p.s.i.), gradually increased to 13-year-old trees (265 p.s.i.), but was slightly lower again for 17-year-old trees (255 p.s.i.). A test in the second orchard showed bark strength gained fast from 4 to 9 years, but only slightly from 9 to 23 years.

A check of prune varietal differences on two different dates in one orchard showed Robe bark strength to be lowest, with French next (25 to 50 p.s.i. greater), and Imperial highest (10 p.s.i. over French). A test in another orchard again showed Robe lowest, but Imperial next (25 p.s.i. greater), and French highest (20 p.s.i. greater). An interesting observation from the results of this test was the large difference (100 p.s.i.) that was evident for the same age trees in two different areas in Sacramento Valley. A test was conducted in the University orchard to compare prune, apricot, peach, and almond species. Bark strength measurements showed Texas almond, Blenheim apricot, and Red Haven peach to have approximately the same strength (270 to 280 p.s.i. dry) and French prunes to be slightly lower (240 to 250 p.s.i.).

Tests of the attachment of shakers to "bolts" permanently installed in trees were continued. Lag screws, screw nails, and reddy bolts of 1/2- to 1-inch diameter were tested in both limbs and trunks. Screws and nails were installed in holes one-eighth-inch smaller in diameter than the fastener, and the bolts in holes one-eighth-inch greater in diameter. Lag screws seem to be most practical to install considering ease and speed of installation cost and minimum reduction of strength of limb. During field trials the smaller size fasteners were found to be subject to withdrawal, flexure, and breakage. Larger sizes were found to be satisfactory when the shaking force was approximately in line with the bolt ($\pm$ 20 to 30 degrees). With excessive side force, mild steel failed in bending and high strength steel resulted in crushing of wood adjacent to the bolt and near the bark. Both problems were minimized by minimum overhang of the fastener and results may be satisfactory.

A small compact shaker unit was developed and constructed to permit perpendicular attachment on limbs to eliminate the problem of longitudinal failure of bark which results when shaking at too great an angle. Preliminary tests were favorable and presently a powered arm for supporting and positioning the shaker unit is being developed.

11. Coffee harvesting. A coffee-harvesting labor supply outside the farm family is practically nonexistent in Kona, Hawaii. Since harvesting accounts for over 70 percent of the total farm labor input for coffee production, a grower's income is limited by the amount of coffee the farm family can harvest. This income is marginal and the Kona coffee industry will perish unless an economically feasible method of increasing harvest rate is developed. The Agricultural Engineering Research Division of the USDA and University of Hawaii are working on a cooperative project to accomplish this goal. Mechanical tree shakers have been designed and tested. The results demonstrate the feasibility of removing fruit by machine. A small scale model of a collapsible catching frame which can maneuver among closely spaced trees and rough, uneven terrain was constructed. The principle of pneumatic conveying was tested on coffee cherries and the results were entirely satisfactory. A small hand-held vibrator, manufactured commercially for cultivated blueberries, was obtained and tested. Results of short period tests show that the unit increases harvest rate, in a complete fruit removal operation, over that of a good hand picker. Results of measurements of coffee tree accelerations due to mechanical shaking illustrates what is happening to the tree. This information is useful in evaluating the present shaker and offers suggestions for improving it or designing a different one.

D. Forage Harvesting Equipment

1. In Georgia, the effect of vapor barriers, between the ground and the Coastal bermudagrass on drying rate, was insignificant when drying conditions were good and the ground was dry when the hay was cut. Under poorer drying conditions and with damp ground, however, hay placed on a vapor barrier dried more rapidly. Although hay on the vapor barrier dried more rapidly, it did not reach safe baling moisture with only 1-day's drying. Since hay without a vapor barrier could also be baled the following day, the use of a vapor barrier does not appear feasible.

2. Low moisture alfalfa silage. A rapid, accurate method for determining losses in harvesting hay-crop silage was developed. The use of a windrower and pickup chopper gave dry matter yields similar to direct-cut chopping. Conventional mowing and raking before pickup chopping resulted in lower harvested yields, regardless of the moisture content of forage during raking. The dry matter bulk densities of hay-crop silages stored in tower silos were little affected by lengths of cut or by original moisture contents. The average density of low-moisture silage that had been chopped with a machine set at three-fourths inch theoretical cut was only slightly less than that chopped more finely by a machine set at one-fourth inch cut. Also, the dry

matter in low-moisture silage was only slightly less dense than that of high-moisture, direct-cut silage.

E. Forage Seed Harvesting Equipment

1. Optimum moisture content for seed harvesting. At Corvallis, Oregon, research on the time of harvest was continued on bluegrass and orchardgrass to determine the optimum stage of maturity at which to cut the crop in order to obtain the maximum quantity of pure live seed. In bluegrass harvesting, the 25 percent seed moisture seems to be the optimum time to windrow the crop, but this will require more research to be conclusive. In orchardgrass harvesting, when the crop was cut at 44 percent seed moisture, the maximum quantity of pure live seed was obtained. The 1964 yield was 776 pounds per acre when cut at 44 percent moisture, as compared to 304 pounds per acre when cut at 18 percent seed moisture. By cutting the crop at 44 percent seed moisture, the increase in seed harvested on the present acreage would far exceed the 4.5 million pounds imported each year. A simple inexpensive moisture meter that uses the exhaust heat from a tractor, truck, or any other internal combustion engine was developed to determine quickly and easily the seed moisture in the field. The research on six crops indicates that seed moisture is a reliable method of determining seed maturity.

2. Development on components for cutting, picking up, threshing, and cleaning field seed crops. A rotary cutter was altered for the purpose of cutting and removing seed crops from the field. When harvesting crimson clover with the altered machine, 94 percent of the crop was cut and delivered to a wagon with very little seed damage. The unit was less effective in harvesting row crops, as only 50 percent of the production of bluegrass, orchardgrass, and birdsfoot trefoil planted in rows was saved. However, the overall test results indicate that the rotary cutter can be a satisfactory replacement for the cutter bar on a combine for a number of seed crops.

F. Long Fiber Crops Harvesting Equipment

1. Research on developing harvesting and farm handling equipment for bamboo has included the attachment of a 44-inch cut-off saw to the sansevieria harvester in order to further test the saw as a method of large-scale harvesting. This machine has a slow forward travel, ranging from .35 to 1.25 miles per hour which should be adequate for the initial tests to be made in June 1965. Bamboo plantings at Belle Glade have shown good growth but on the sandy soils near the coast, growth has not been good except for one variety, Bambusa tuldoidse. With the lack of growth and also the lack of interest in large-scale plantings, there seemed to be little need to develop a large-scale harvester for paper pulp. However, sufficient study has been made to indicate that the shear-type tractor attachment used for land clearing or the saw can be made to work if the need ever arises for such a harvester commercially.

2. Early field testing of the harvester-decorticator built for sansevieria revealed the need for clearing space in front of the decorticating wheels

and also at the approach to the feed tables so that trash which is composed of short leaves, weeds, etc., can fall through to the ground without jamming the passageway for the leaves. After making these changes and other minor adjustments, the machine has given very good performances. On several tests, slightly over 2,900 pounds of clean dry fiber per acre were harvested with an efficiency of over 70 percent. The lack of power on the decorticating drums is the limiting factor in the capacity of this prototype machine. A new machine of sufficient size and capacity would be required in order to determine the cost of producing sansevieria fiber on a commercial scale.

3. Research on the development of improved harvesting and processing machinery and methods for the production of kenaf and other jute-like fibers included plantings at Belle Glade, and near Lake Worth, Florida, for the purpose of testing a tying attachment on the field harvester-ribboner. This attachment replaces the several men needed to tie the ribbons into bundles as they come from the machine. The limited amount of testing done last summer and fall indicates that this attachment will be quite satisfactory.

The field harvester-ribboner, complete with tying mechanism, as well as the squeeze roller-type washer, can now be considered ready for commercial use. The ribboner will give crude ribbons suitable for spinning directly in the coarse process, while the retted material is suitable for finer yarns needed for better products. A machine similar to the research model was built commercially for Sudan, Africa and made ready for tests there.

Studies were also made of machinery developments for kenaf, jute and like fibers in Europe and of growing and processing developments in Asia.

G. Oilseeds and Peanut Harvesting Equipment

1. Castor combine for harvesting damp or dry castor beans. Over 25 percent of the cost in production of castor beans is in harvesting and hauling (based on average yields and custom harvesting). Present machines require completely dry capsules for effective harvesting. Frequent adverse harvesting conditions result in small acreage per machine and large harvesting costs per acre. This cost can be reduced through development of a combine-type harvester which will operate effectively on damp or dry castor beans. Development of this type machine was continued this year. The addition of an aspirator-type cleaner as an integral part of the huller was effective in removing loose hulls. This produced a clean product in the bin with less cleaning load on the combine screens. Harvester components were designed to reduce field losses, amount of cracked and broken seed, and to gather the plants into the header without "chokes." Operating the harvester under widely varying crop conditions showed the need for further development for effective and efficient operation. Seed breakage was found to be excessive in the conveying system from the combine sieves to the storage bin. Data and information obtained should be valuable in further development of castor harvesters.

Development of moving brush row seals. Simplification of an attachment is needed for effectively gathering castor beans under widely varying crop conditions. The principle of using moving brushes on the combine header to act as conveyors for moving loose castor beans into the header (invented on this project) proved to have merits for further development. A new, more rugged, design, which will permit replacement of worn segments, needs to be incorporated for further development of the attachment.

2. Development of tung harvesters and windrowers. Tests showed the amount of tung left on the ground by hand labor was greater than with a mechanical harvester. In addition, the scarcity of dependable labor for hand harvesting and increasing labor costs each successive year is a problem facing the tung growers. Modifications made on the experimental harvester to move windrowed tung onto the elevating conveyor were shown to be effective under most field conditions. Improvements in use of air, at strategic locations, for separating large masses of leaves from tung fruit were effective on dry leaves but were not sufficient to remove all of the leaves when wet material was encountered.

Additional changes and tests are planned for improving the harvester to operate under a wider range of conditions. The use of wire-bound boxes of approximately 1,000 pound carrying capacity and transported with a tractor front end fork lift from harvester to highway transport trailers has proven to be effective and efficient in handling harvested fruit on the project for 3 consecutive years. Some 76 boxes using this principle of handling the harvested crop were in use this year by growers.

Tung hullers. A commercial walnut huller using a concave wire brush and rotating cylinder was tested on tung fruit. This principle of hulling showed promise as an effective way in removing outer tung hulls without breaking the kernels. The huller had a maximum capacity of 3 tons per hour and was effective on fruit containing 30 to 40 percent moisture w.b. The huller was less effective on tung of lower moisture content. Further investigations using this huller along with development of separation equipment for removing loose hulls are planned.

3. Pruning of tung trees to facilitate the use of equipment in production and harvesting. Pruning the lower limbs of 7-year-old established trees to approximately 5 feet above the ground did not show a significant difference in yield than trees not trimmed during the first year. The experiment will be continued to determine whether yields may differ in subsequent years. Growth measurements were made of seedling trees which are headed at approximately 5 feet above the ground and for natural heading trees. This is a long-time experiment to determine the yield potentials of normal growth tung trees to high headed trees suitable for mechanical harvesting.

4. Peanut digger development. An elliptical wheel assembly installed on an experimental peanut digger aids in removal of soil from the peanuts. By using a longer conveyor and installing each elliptical wheel with its major

axis at right angles to the adjoining wheel, the problems of vine wrapping were reduced. Other refinements are planned to improve the overall digger performance.

5. Specific gravity, size and grade relationship studies with Virginia 56R green harvested peanuts show that both immature and mature peanuts range in specific gravity from 0.62 to 0.98, and that a satisfactory separation of mature from immature nuts cannot be made based on this characteristic. About 60 percent of the foreign material, however, can be removed by pneumatic equipment. Seventy-seven percent of the immature peanuts were one-half inch or smaller in diameter, whereas 97 percent of the mature peanuts were one-half inch or larger in diameter. A separator consisting of two vibrating screens was designed on the basis of these results. Material riding the top screen, 7/16- x 4-inch slots, contained 95.5 percent of the better grade unshelled peanuts, 28 percent of the immature peanuts, 16 percent of the loose shelled kernels and 50 percent of the foreign material. Material riding the second screen, 1/4- x 3-inch slots, contained about 62 percent of the immature peanuts, 70 percent of the loose shelled kernels, 37 percent of the foreign material and a small quantity of small, unshelled peanuts. The material passing this screen, unshelled immatures, foreign material and split kernels, could be discarded with little or no economic loss. The separation of high moisture immature peanuts and foreign material improves quality and reduces drying problems and should reduce the potential of A. flavus development. The cleaning studies will be emphasized.

H. Potato Harvesting Equipment

1. Mechanical injury of potatoes. Bruising continues to be one of the major problems in harvesting and handling potatoes. The impact instrument, which was developed on this project to measure susceptibility to bruising, was modified and the method of evaluating injury changed. In 1963, tubers were classified as injured or not injured. In 1964, four classifications of injury were recorded (none, slight, moderate, severe). Index numbers were applied to injuries (0, .1, .5, 1.0) and the sum for a 50-tuber sample was tentatively considered to be the injury index of the sample. In order to have a reproducible procedure for measuring the extent of an injury to a tuber, a device with a curved knife and gaging pin was constructed. This device proved to have considerable merit as a research tool. This knife may also be of value to the inspection people who grade potatoes. It now seems probable that a technique can be developed that will provide an injury index that will bear a reliable correlation with relative injury susceptibility.

Additional data were obtained on the cantilever flap rubber cushioning which was mentioned in last year's report. Results showed that it did not shorten chain life and does result in less bruising and better soil separation. Cantilever flap rubber cushioning is now available commercially.

2. Multi-row harvesting of potatoes. Potato harvesters have become more expensive and heavier each year. Anything which can be done to increase the acreage a unit can harvest and reduce soil compaction is desirable. Commercial direct-indirect (multi-row) harvesting methods (described in last year's report) were studied. Such advantages as machine cost savings of 20 to 30 percent were noted. Disadvantages such as lack of suitable devining equipment and need of modification of present equipment owned by growers were also observed.

3. Dust applicator for seed potatoes. Studies conducted by pathologists have shown that cut seed treatment prevents seed piece decay. The application of chemicals by dipping these seed pieces in a solution has serious limitations. Although dusting has many advantages, no commercial equipment for uniform application insuring complete coverage of the seed piece surface is available. Several experimental units were constructed to (1) cover cut surfaces completely and uniformly, (2) contain dust to avoid dust contamination of this work area, and (3) have adequate capacity for commercial usage. The last unit met requirements (1) and (3) but does not contain the dust adequately. Modifications are being made and the unit will be tested in the spring and fall of 1965.

I. Sugarcane Harvesting Equipment

1. Harvesting hurricane-damaged sugarcane in Louisiana. Harvesting efficiency and trash determinations were made on the USDA cutter-cleaner-loader during the latter part of October, which was approximately 4 weeks after a severe hurricane. Harvesting in the direction that sugarcane leaned was more effective when compared to the effectiveness of conventional machines. Harvesting efficiency averaged 83.5 percent in variety C.P. 52-58. The machine uprooted considerable amounts of stubble when operating against the direction of sugarcane lean and averaged 68 percent harvesting efficiency. (The normal efficiency when operating in upright cane with the USDA machine is 95 percent.) Many conventional harvesters were placing less than 50 percent of the cane in a heap row. Consequently, hand scrapping was necessary and found to be expensive.

2. Mechanically removing tops and leaf trash from sugarcane. A major problem of harvesting recumbent sugarcane is to remove and separate the leaves and tops from the cane stalks. This investigation was initiated in June 1964 with the Louisiana State University, Agricultural Engineering Department under a 3-year research contract. A comprehensive search and review of literature on methods for removing extraneous material from the cane was made and a report prepared. Laboratory equipment was developed and tests initiated to determine the effectiveness in removing leaves when subjecting sugarcane plants to high temperature flame and an air blast. Equipment and instruments for more detailed study are being obtained. This work is cooperative with the Louisiana State University Agricultural Engineering Department and the Audubon Sugar Factory.

3. Harvesting recumbent-type sugarcane. Methods of gathering, orienting and cutting recumbent cane are being studied in order to harvest cane without damaging the stubble. This is a new line project, and the work is being conducted at the Everglades Experiment Station, Belle Glade, Florida, in cooperation with local sugar producers and mills. An observational study of two experimental harvesters has been made; one harvester using a 36-inch diameter ground knife and chain pickup, the other using two 12-inch diameter ground knives with a spiral-auger pickup. These have operated on two soil types both under wet and dry conditions. High speed photography will be used in studying the stubble and ground reaction with these two machines.

4. Mechanization of sugarcane production in Brazil. Two experiments are underway at the University of Sao Paulo, Brazil, under research contract using PL 480 funds. This work is concerned with minimum tillage in sugarcane and with the development of a mechanical harvester.

When two varieties were planted on unplowed pasture and compared with conventional seedbed preparation, the following conclusions were made: (1) Germination is not affected; (2) tillering (underground branching) was better in plowed plots; (3) there was no difference in soil moisture during drought-stress periods; and (4) weed population was the same.

A prototype stripping unit using cylinders with three-eighths-inch diameter wire rope was side-mounted on a tractor to strip a row of standing cane. The cane had been previously topped by hand. A rotor speed of 650 r.p.m. with a forward tractor speed of 1.8 m.p.h. gave best results. A reasonable stripping job was obtained although no trash measurements were made. The wire rope damaged the cane and was broken at the point of attachment.

J. Tobacco Harvesting Equipment

1. Handling of stalk-cut air-cured tobacco on portable curing frames. This study is being conducted at a research tobacco curing barn with a clear-span pole structure furnished by the University of Kentucky Experiment Station. Both wood and steel portable frames have been handled at the field and barn with a front-loader tractor. Stalk-cut tobacco was placed in the portable frames at bulk densities varying from 24 to 48 square inches per stalk in plan area. The levels of bulk density had no significant effect upon curing based upon government graders' evaluation. Labor requirements of 15 to 20 man-hours per acre for this housing procedure correspond to 40 man-hours per acre required for conventional practice. Objectives of further research are (1) continue study of labor and equipment performance, (2) determine effect of prolonged wilting of tobacco on the frames prior to housing, and (3) determine environmental characteristics and quality of cure resulting from variation of housing procedure.

Handling of stalk-cut air-cured tobacco on vertically suspended strings. A system is proposed utilizing a tobacco harvester having the function to fasten the base of cut tobacco to continuous twine. The "chain" of stalks

is to be conveyed to a wagon drawn by the tractor-attached harvester. A portable drum-hoist at the top of a modified conventional air-cure barn will be used to pull the tobacco from the wagon. Control and power circuits for hydraulic or hydraulic and pneumatic harvester components have been designed. Curing tests have indicated satisfactory air-cure using the proposed procedure of handling.

Burley tobacco stalk strength properties. The objective of this work is to determine the plant's response to external forces which may be exerted by machines used to handle the crop. Three aspects of stalk strength were investigated: (1) Resistance of the stalk to crushing forces perpendicular to the long axis; (2) the distance a split in the stalk will progress; and (3) flexure tests to determine the flexure modulus of elasticity.

Results: (1) The mean force resisted at the base of the stalk was 314 lbs. when using crushing jaws 1/2-inch wide, and 354 lbs. with jaws 1/4-inch wide. This difference was not statistically significant at 5 percent level. Similar results were obtained when the forces were applied 4 inches from the base of the stalks. There were significant differences among the three testing dates which were 1 week apart due to a decrease in resistance with maturity.

(2) The stalks in this investigation were split initially at the base, the stalk haves were separated laterally a distance of 4 inches, and the distance a 1-inch x 1-inch block could be inserted into the split was measured. The mean distance of insertion ranged from 10.2 inches the first week of testing to 11.1 inches for the third week. Though these values increased slightly with maturity they were not significantly different.

(3) Flexure modulus of elasticity of stalk material was determined for small clear specimens excised from the woody portion of the stalk. These specimens were tested in flexure in a manner similar to ASTM specifications for wood except on a reduced scale (7/32-inch x 7/32-inch x 3 1/16-inch test span). Similar tests were also made on sections of intact stalk from the same stalks to check the applicability of the values to intact stalks. The flexure modulus of elasticity of the stalk material was determined to be 406,000 p.s.i. for the mean of 40 specimens from 20 stalks with a standard deviation of 76,400 p.s.i. The mean modulus of elasticity determined from the intact specimens, assuming them to be of uniform cross-section over the test span, was 396,000 p.s.i. with a standard deviation of 85,300 p.s.i.

Development of a mechanical burley tobacco harvester. Field tests of the spiral-held spear were conducted in an effort to determine: (1) Leaf loss as affected by height of spearing and ground speed; (2) leaf loss as related to the point of contact of the leaves with the spearing mechanism; (3) leaf loss as affected by leaf-parting devices (powered and stationary); and (4) power requirements of the spearing unit.

Results: (1) The total number of leaves lost per plant ranged from a mean of 0.94 at 0.56 m.p.h. and a spearing height of 10 inches, to a maximum of 2.69 at 0.56 m.p.h. and a spearing height of 16 inches. The difference due to different ground speeds was not statistically significant; however, the difference due to different spearing heights was significant.

(2) Greatest leaf loss was found to be below a point 2 inches below the spear point. Guides for centering the stalks onto the spear point were in this area and contributed to this loss of leaves.

(3) No significant difference was found between four types of leaf-parting devices.

(4) Power requirements of the spearing mechanism ranged from a minimum of 0.59 hp. to a maximum of 0.84 hp.

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AREA 5: CROP PREPARATION AND FARM PROCESSING (EXCEPT COTTON)

Problem. The programs of research in this area are concerned with the development of better methods, techniques, and equipment for use on farms for the initial preparation for market or the processing of farm products to increase efficiency in the use of labor and equipment, and to preserve quality and prevent spoilage and damage from mechanical handling. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. The underlying principles that pertain to the cleaning and drying of different crops, curing of tobacco and peanuts, and sorting need to be determined. The methods for processing farm crops are largely dependent on production practices and dictated by future handling or storage requirements. Consequently, this requires interdisciplinary collaboration in the creating of a completely mechanized program of crop production.

USDA AND COOPERATIVE PROGRAM

The Department's effort in this area constitutes a long-term program involving agricultural engineers and statisticians engaged in both basic and applied research on the engineering phases of crop preparation and farm processing. Seed cleaning research is currently being conducted at Corvallis, Oregon, in cooperation with the Experiment Station and private industry. Research on tobacco curing and sorting is cooperative with the Experiment Station at Lexington, Kentucky. The decorticating, retting, and cleaning of long fiber crops is carried on at Belle Glade, Florida, in cooperation with the Everglades Branch Experiment Station, the Office of Defense Mobilization, and industrial fiber users. Research on the drying of grain is cooperative with the Experiment Station at Ames, Iowa, equipment manufacturers, and farmers. Forage processing is under study at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Coastal Plain Experiment Station. Manufacturers cooperate through loan of equipment. Research on the processing of tung nuts is conducted at Bogalusa, Louisiana, in cooperation with the Mississippi Experiment Station and industry. Drying of castor seed is cooperative with the Oklahoma Experiment Station.

The Federal engineering effort devoted to research in this area totals 12.6 professional man-years. Of this number 2.5 are devoted to seed cleaning, 2.0 to curing tobacco, .5 to decorticating, retting, and cleaning long fiber crops, .5 to drying of castor seed, 4.9 to drying of grain, 1.5 to forage processing, .2 to tung nut processing, and .5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Many freshly harvested agricultural crops must be subjected to early treatment in order that they may retain as much as possible of their original qualities. The state agricultural experiment stations are involved in both basic and applied research studies which have as their broad objectives the development of improved methods, equipment and techniques for preparation and processing of farm crops to preserve quality and prevent spoiling while in storage.

The scope of the current program may be best illustrated by describing it in broad areas of study.

Drying or curing investigations are in progress on forage crops, cereal crops including rice, feed grains including grain sorghums and soybeans, nuts, tobacco, peanuts and coffee. Farm processing studies are under way for forage wafering and hay storage; precooling of freshly harvested crops such as citrus, sweet corn and vegetables; pre- and poststorage treatment of potatoes; dehydration and mechanical dewatering of crops; seed and grain cleaning and separation; and trimming, peeling, and juicing operations for crop marketing.

Closely associated with these studies are development and adaptation studies of flow systems, equipment and packages to move products without damage into and out of storages and to the market place.

Much of this research is cooperative with the Department.

A total of 38.6 man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seed Cleaning

1. Seed cleaning research applied to specific problem mixtures. Processing research was conducted on 30 seed mixtures furnished by the seed industry in order to develop techniques, procedures, and equipment to make the separations that would salvage the crop seed.

The technique of microscopically measuring the length, width, and thickness of the crop seed and its contaminants, has proven very effective. This technique was used to select a 6 x 26 slotted-hole screen which proved most successful for removing rattail fescue from creeping red fescue. In this case, the purity was raised from 85 to 99.6 percent.

Data obtained by this technique were used to design a special indent cylinder that would remove six of seven kinds of weed seeds commonly found in bentgrass. Oregon's annual production of bentgrass is valued at more than $2,250,000. The special indent cylinder, designed from the research data, with indent pockets measuring 0.035 inch in diameter and 0.012 inch in depth

was used to lift red sandspurry from a 20,000 pound lot of Penncross bentgrass at the rate of 50 pounds per hour, thereby reducing the weed count from 2.5 percent to .04 of 1 percent. Removal of the weed seed increased the value of the seed $.85 per pound, or $17,000 for this one seed lot. The same procedure was used to design a special indent cylinder with pockets 0.062 inch in diameter and 0.019 inch in depth to remove pigweed from alfalfa. This development can save the seed industry several million dollars annually.

Another development is a machine that separates seeds by differences in resiliency. This machine reduced the percentage of ryegrass from 5 to 0.5 percent by "bouncing" ryegrass out of orchardgrass.

The surface-textured deck vibrator separator research tests have resulted in several additional difficult separations being made. A 500-deck machine of this type was constructed by a processing plant in accordance with specifications furnished by the project's personnel. The machine is now being used in a commercial seed processing plant to convert ladino clover screenings into salable seed at a rate of 200 pounds per hour. It is estimated that $19,000 worth of seed will be saved in a single season at the one processing plant.

2. Development of centrifugal-pneumatic seed separator. Considerable progress was made in the development of a pneumatically cleared vertical rotating screen. Preliminary tests indicate that when operated at 300 r.p.m., which generates a centrifugal force 10 times the pull of gravity, the unit will make a more efficient separation at 3 times the capacity of that of the conventional flat vibrating screen of the same surface area. Materials run in the machine thus far have been wheat, crimson clover, fine fescue, sunflower seed, and sawdust. The unit is a revolutionary step in screening, and has already attracted the attention of machinery manufacturers; for example, the farm machinery companies are interested in the unit for use on combines, the air-screen manufacturers are interested in it for seed processing, and other manufacturers such as mining and building contractors are interested in it for their numerous screening and sizing operations. The manufacturers in all three areas have obtained detailed information on the machine and have constructed test units. When the centrifugal screen machine is fully developed, it is estimated that it will mean a saving of several million dollars annually to the above industries.

3. Modification of seed-length separators. The scientific approach of microscopically measuring dimensions of seeds in problem seed mixtures resulted in the development of a number of special indent cylinders that make specific separations.

The seed industry is already using special cylinders to separate red sandspurry, yellow cress, toad rush, mouse-ear, and other weed seeds from the bentgrass, and to separate pigweed from alfalfa.

The amount of seed saved is estimated to add 2 million dollars annually to the farmers' revenue.

B. Tobacco Curing

1. Thermal conductivity and specific heat of burley tobacco during the cure. These basic engineering properties were determined for post-harvest conditions, from the turgid state through the curing process. Mathematical expressions for these leaf properties as functions of moisture content and density were derived. The findings were in agreement with basic heat theory for solid materials. There are no plans to continue this line of research.

Mass and energy balance of burley tobacco during the cure. In burley tobacco mechanization, the continuing search for new and improved methods of harvesting and curing has brought about the need for a thorough understanding of the curing process. Any process involving the heating or cooling of a biological material requires a thorough knowledge of its thermal properties before a mass and energy balance can be written for the process.

The lack of information reported in the literature and the potentials of applying this mass and energy balance to a controlled environment tobacco curing system has prompted this study with the objective being to write a mass and energy balance for the curing process. A thorough search of the literature revealed the mass and energy balance to be affected by the following: Temperature, humidity, air flow, density, oxygen and carbon dioxide concentrations as well as the stage of cure. A respiration chamber has been designed to give a continuous measurement of the heat produced, carbon dioxide and water evolved, oxygen consumed, total weight loss and air flow. Chamber conditions will be maintained at various levels of temperature and humidity within the curing range of burley tobacco. The future plans include construction of the chamber and conducting tests, with both field- and greenhouse-grown tobacco, on the entire plant, or on leaves or stalks for determining the respiration heat in order to write a mass and energy balance for the curing process.

Measuring the coloring rates of primed burley leaves with time-lapse photography. Basic information concerning the influence of temperature, humidity and air flow on the curing rate of primed leaves is needed in the design of curing systems which will enhance the usability of the end product. The objective of this study was to determine the coloring rates and drying rates of selected leaves as a function of these three environmental factors. From a series of 84 observations, equations were developed which give the relative importance of each environmental factor. It is significant to note that while the coloring rate is significantly influenced by all three environmental factors, the drying rate is significantly influenced by the specific humidity deficit only. This work is essentially completed and the results will be summarized for a technical publication.

Development of a 2-week curing cycle for primed burley tobacco. Past experience with bulk curing of primed burley indicated a need for a longer curing schedule than 1 week. The objective of the present work was to determine the acceptable levels of humidity for curing primed burley at constant temperature and air flow conditions. The tests were conducted at biweekly intervals on leaves which were primed from the upper half of the plant. Humidity treatments were 60, 70, and 80 percent r.h. (relative humidity). A standard schedule consisted of 90° F., 50 percent r.h. for 1 day; then 2 replications at each of the 3 humidity levels (60, 70, and 80 percent) for 11 days; followed by 150° F., 20 percent r.h. for 1 day for final drying; and 80° F., 87 percent r.h. for 1 day for "casing" the tobacco. These treatments were repeated for three primings. Judgments based on government grades and current price supports indicated differences in value only between primings, with the value per pound for the last priming being significantly lower. However, visual observations indicated the high humidity treatment to be superior for producing an acceptable color in the cured tobacco.

This work will be continued with the objective of measuring the progress of the cure by assaying certain chemical constituents in the leaf for the purpose of judging the progress of the cure. Comparisons will be based on malic and citric acid contents of both primed and unprimed leaves.

C. Grain Drying

1. At Ames, Iowa, studies are underway for isolating the factors that enter into rational design of drying equipment and for developing quantitative descriptions of their relation to economic design. Measurements of the rate of moisture loss in thin layers of kernels are being made to determine the separate effects of air temperature, air humidity, air velocity, initial grain moisture, initial grain temperature, and other grain properties on moisture movement. Also observations are being made on the effects of contraction and expansion of grain as its moisture content changes. This year's tests have included soybeans as well as corn. The data from corn show a response to drying conditions that are similar to, but more complicated than, that found for grain sorghum kernels. This difference is presumed to be due to the nonspherical shape of the corn kernel. Tests with relative humidity as near to zero as possible indicate that some of the moisture that might be removed from a kernel at high temperature (for example, 200° F.) cannot be removed even with a very extended period of exposure at zero humidity when the temperature is lower (for example, 120° F.). This suggests that a portion of what may be defined as "moisture" at one temperature may become a part of the "dry matter" at another temperature.

2. Studies of the drying zone in mechanical grain driers were continued through use of laboratory model drying bins. The drying zone refers to that part of the grain in a drying bin in which drying is actually taking place at any given time. The zone moves through the grain but, in general at any specific time during drying, part of the grain is drying, part is already dry, and part is still at its initial moisture. The temperature and moisture

gradients in the drying zone determine the efficiency and the required drying time in any drier. Accurate definition of the drying zone in terms of grain moisture, air temperature and humidity, rate of airflow, etc., would permit rational design of drying equipment. While much progress has been made in relating these factors to the drying zone, drier design still remains an art without the support of adequate design data.

3. Effects of mechanical damage to field-shelled corn. Attempts have been made to evaluate the damage to kernels in samples from various shelling treatments by immediate inspection. The severity of damage by various machines is difficult to assess and little progress has been made. The most promising method so far appears to be treating the samples with fast green dye so the skin breaks become more apparent. In a field test with different types of shellers and various row spacings no preference could be detected for any machine or method. Tests of flaming corn ears to partially sterilize the grain and to temporarily harden the kernel surfaces prior to shelling did not improve the condition of the corn after shelling.

4. The time limitation on deep bed or in-storage grain drying systems is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The factors which influence the rate of growth of the microflora are grain moisture, temperature, and the amount of physical damage of the grain. It is the purpose of this study to evaluate the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration.

Generally the tests show a tendency for the CO_2 production rate to increase with time, but for this tendency to be less pronounced at high temperatures. In one series the rate was almost constant at 75° F. In another, this did not occur below 110° F. Further research will be required to establish relationship between rate of CO_2 production and different combinations of time and temperature.

The effect of mechanical damage on permissible drying time reported previously has been further confirmed. However, damage inflicted by razor cuts had far less effect than that caused by field shelling. Whether this difference is due to the inoculation provided in the shelling mechanism or whether a simple skin rupture is only a small part of the mechanical damage caused by the machine remains to be determined.

D. Forage Processing

1. Tests with a stationary wafering machine showed that a wide variety of products could be wafered or cubed. Coastal bermudagrass, peanut hay, gin trash and corn cobs and husks were all wafered without grinding. Due largely to an inefficient feeding system, the production rate was low and the power requirements high. With modifications, it appears that this process might be feasible.

Tests indicate that dehydrated and pelleted small grain forage retains the milk stimulant present in the fresh forage. Although the material pellets easily, the energy costs for processing are just about double that for processing Coastal bermudagrass. The increase in energy is due to the large amount of water that must be removed for each ton of dry matter.

A 3-year study of systems of utilization of Coastal bermudagrass showed that dehydrated and pelleted hay gave the best animal performance. Following, in order of decreasing rate of gain, were dehydrated hay, continuous grazing, rotational grazing, strip grazing and green chop. The calculated gain per acre for the two processed treatments was about 300 pounds per acre more than for continuous grazing. The processing energy costs were $39.02 per acre for dehydrating and pelleting and $34.00 per acre for dehydrating only. This concludes these studies. Next year a study of the processing costs and relative value, measured by animal gains, for pellets made from dehydrated, partially field-cured and field-cured hay will be undertaken. Tests will be made using 4- and 6-week old grass.

Effect of unit processes involved in dehydrating and pelleting on the economically important constituents of Coastal bermudagrass and Pearl millet. Preliminary tests were run to determine the minimum sample size for testing the effects of each of the processes, dehydrating, grinding and pelleting, and the effect of additives on these constituents, and on the feasibility of dehydrating and pelleting millet which was older than 4 weeks. During the coming year these tests will be run and information developed for linear programming for use by the feed processing industry.

2. Chopping or grinding hay prior to wafering resulted in wafered products having different physical and nutritional qualities. Baled hay was flail chopped, ground through a large screen or through a small screen, and then wafered in a stationary system. The most dense wafered product with the least amount of fines was made from the hay having the smallest size particles. Sheep ate this product in the greatest quantities.

Physical qualities of samples of wafered hay were related. Higher bulk densities of samples of wafered hay were associated with a lower percentage of fines (material not in wafers). However, the bulk density of the fines tended to be higher for those samples with higher overall bulk densities. Within the limits experienced, the percentage and bulk density of fines had little effect on the overall bulk density.

E. Tung Nut Processing

1. Farm processing of tung nuts. Hauling and milling charges for tung nuts with moisture of 35 to 50 percent is costly to the grower. If stored, the moisture level should be reduced to prevent deterioration. Pilot drying tests using up to 100 c.f.m. of 150° F. air per square foot floor showed the drying zone of high moisture tung under these conditions was approximately 4 feet. Drying zone refers to that part of the tung in the bin in which

drying is actually taking place at any time. Additional tests are planned to determine optimum drying conditions.

F. Drying Castor Seed

1. Resistance of hulled and unhulled castor beans to air flow. Conditioning of castor seed is needed when moisture is excessive to make the product acceptable to buyers as well as to prevent increased acid content and oil quality deterioration. Basic relationships of air flow rate, resistance to air flow, moisture of material, density of material, and depth of material, for data obtained previously, were analyzed by multiple regression. Exponentional equations were found to express the data adequately. These equations may be used as guidelines for designing driers and drying requirements for hulled as well as unhulled castor beans.

Equilibrium moisture of castor seed. Equilibrium moisture of castor seed at different temperatures and humidities is needed to know the limits for efficient forced drying. A preliminary study of castor seed exposed to several atmospheres of relative humidity at room temperature showed the seed to have the following moisture contents: Approximately 7.5 percent moisture (w.b.) (wet basis) when exposed to an atmosphere of 75 percent relative humidity; approximately 5.3 percent moisture (w.b.) when exposed to an atmosphere of 53 percent r.h.; approximately 4.4 percent moisture (w.b.) when exposed to an atmosphere of 37 percent r.h.

Drying requirements of high moisture unhulled castor beans. Unhulled castor beans containing high moisture cannot be hulled effectively. In addition, castor beans containing high moisture (above 6 percent w.b.) will result in oil quality deterioration when subjected to certain drying conditions. Factors affecting the drying of castor beans (resistance of air flow, temperature and quantity of air density, depth and condition of castor beans) are needed to design effective driers. Drying studies were made using 120° F. temperature air at several rates on unhulled castor beans of different moisture contents, also using several bin depths and densities of material in bins. Unhulled castor beans of 30 percent w.b. moisture were found too wet for satisfactory drying. A depth of approximately 3 feet was found to be maximum when drying 14 percent w.b. moisture castor beans using 70 c.f.m. per square foot floor, 120° F. air at 3 percent r.h. Static pressure to air flow was reduced slightly as the material became dry while the drying air volume and temperature were kept constant. A guide to efficient drying would be to reduce the air volume or temperature or both when the air leaving the drying material does not contain a maximum of moisture.

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AREA 6: COTTON GINNING

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed and trash, packaging, and sampling in order to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Rapid methods of harvest which have come into widespread use during the past 20 years have been successful because of the advances made in cotton ginning research.

Although developments growing out of the USDA Ginning Research Program have been revolutionary, there are many problems yet to be solved, some of which are growing acute. There is increasing need for further automation of the ginning processes to effect better quality control and reduced labor costs.

In their quest for lower unit costs, mills are continually demanding more and more of cotton as they increase machine and processing speeds. At the same time the trend continues in the trade to demand cleaner and cleaner cotton. Thus with the farmer gathering more and more foreign matter with the cotton, the cotton trade demanding cleaner fiber for a given grade, and the manufacturer demanding more and more performance, the gin's role becomes most complex. More efficient cleaning equipment which will minimize fiber degradation at reduced labor and power costs is among the more urgent needs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, materials handling engineers, and systems engineers engaged in both basic and applied research on the engineering phases of cotton ginning and handling. Seed cotton handling and storage and seed cotton conditioning and conveying research is currently being conducted at Stoneville, Mississippi, and Mesilla Park, New Mexico. Research on seed cotton conditioning, seed cotton cleaning, gin stands, gin performance and cotton quality, and waste collection and disposal is being conducted at Clemson, South Carolina; Mesilla Park, New Mexico; and Stoneville, Mississippi. Lint cleaning studies, packaging, and cottonseed research is conducted at Stoneville. Research is cooperative with state experiment stations, Economic Research Service, industry, and individuals, as well as with other Divisions in the Agricultural Research Service.

The Federal engineering effort devoted to research in this area totals 16.5 professional man-years. Of this number, 0.6 is devoted to seed cotton handling and storage, 1.3 to seed cotton conditioning, 2.4 to seed cotton

cleaning, 0.8 to conveying, 2.0 to gin stands, 5.5 to gin performance and cotton quality, 0.5 to lint cleaning, 0.5 to packaging, 0.5 to cottonseed, 1.9 to waste collection and disposal, and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is conducted in only two State agricultural experiment stations; namely, Oklahoma and South Carolina. The Department has been specifically concerned in this area for several years and has carried on the major program of research on the engineering phases of premarket cotton processing and handling.

The Oklahoma research involves the adaptation and testing of cotton ginning equipment, techniques and related operations for reducing the cost and delay in handling and conveying seed cotton on the gin yard and in the gin. In addition, evaluations are being made of the quality reductions associated with green and immature bolls in harvested cotton as well as determination of the effects that various combinations of cleaning, drying, and ginning machines have on returns to the producer.

The South Carolina studies are concerned with the development of new principles and techniques for ginning cottons. Characteristics and properties of seed cotton, lint, and seed related to the basic ginning processes are being investigated as well as the effects that various physical actions have on fiber and seed.

A total of 3.3 man-years are devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seed Cotton Handling and Storage

1. Following preliminary investigations last year an unloading system was designed and constructed at Stoneville. The system consists of a specially designed dump trailer, receiving hopper and automatic seed cotton metering device for feeding cotton at a uniform rate directly into the first stage drying system. If successful in tests, a sizable reduction in labor and power would be effective.

Research work was initiated at Mesilla Park during Fiscal Year 1964 on the development of another system for a more efficient and economical seed cotton unloading system. A pilot model system, which is completely different from conventional systems, was designed, constructed, and tested. This system consisted of an inclined unloading ramp, receiving hopper, feeding mechanism, and air-jet conveyor. A side-dumping cotton trailer with inclined bottom was positioned on an inclined unload-ramp which permitted the seed cotton to be dumped from the trailer into the receiving hopper. The feeding mechanism in the hopper bottom fed the cotton at a uniform rate onto the air-jet conveyor. In preliminary tests this system appeared to be practical and workable. Data obtained from performance tests indicated that

a system of this type would require only about one-fifth the horsepower used by conventional unloading systems which would be a reduction from approximately 100 horsepower to 20 horsepower.

B. Seed Cotton Conditioning

1. At Stoneville, using a zero-gradient moving bed drier, 288 test lots were dried and ginned to study the effects of (a) initial moisture content, (b) air-cotton mass ratio, (c) drying air temperature, and (d) exposure period on quantity of moisture evaporated. In each instance, the drying factor relationships were reduced to quantity of moisture removed per pound of fiber per 1,000 B.t.u. available from the drying air and showed that (1) most efficient use of heat resulted from reducing the air-cotton mass ratio, (2) for short exposure periods (5 seconds) the heat use efficiency is directly related to initial fiber moisture content but this relationship becomes obscured at 10-second and longer exposures, (3) the exposure period-moisture evaporated relationship is logarithmic, and (4) under conditions of the test temperature data differences were small and inconclusive except for gross moisture evaporated.

Also at Stoneville a 3-year study to determine the probable effect of agricultural chemical residues on the operation of an automatic drying system based on moisture determination via electrical resistance measurements was completed. Results for the first 2 years have been previously reported. Work on this project in 1964-65 was confined to the study of a soil-fed systemic insecticide. The growth phase, carried out in cooperation with Crops Research Division, is complete and certain findings, such as the delay in development of fruiting structures due to the systemic insecticide application and total final yields, are to be reported in an agronomy periodical. The electrical resistance measurement phase is in progress but has required development of a special measuring circuit.

At Mesilla Park, basic studies are being made on the effect of changes in temperature on electrical resistance of cotton.

Checks were made of a commercial moisture control system employing the principles developed by the Stoneville Laboratory. The system was found to have wide fluctuations in the input temperature. This was called to the manufacturer's attention and the systems are being modified to correct this discrepancy.

An evaluation was made at Stoneville of a new portable cotton moisture meter. On the basis of these tests the manufacturer is modifying the design and changing the meter scale to show wet basis moisture content.

C. Seed Cotton Cleaning

1. A study at Stoneville of the cleaning efficiency of individual seed cotton cleaning machines at various rates of feed and seed cotton moisture contents showed that cleaning efficiency increased as moisture content

decreased. Also, cleaning efficiency, as measured by the Shirley Analyzer, decreased as the rate of feed increased, although these differences were not always reflected in classers grade. Spinning performance was affected as would be expected by reduced moisture content but not by variations in the rate of feed.

The recommended cleaning machinery arrangement for machine-picked cotton was found to be adequate for ground-gleaned cotton in the Stoneville area. More elaborate cleaning removed more foreign matter but it was not reflected in classers grade due to the reduction of color caused by weather damage.

A device for the removal of large foreign matter such as stalks and limbs from seed cotton was developed at Stoneville. It is not intended for use on cotton containing only small trash. Drawings have been turned over to the gin machinery manufacturers and others and some plan to incorporate the principle into existing machines.

Test lots of seed cotton containing 0 to 100 percent tight locks, in 10 percent increments, were prepared and ginned on an 8-saw laboratory gin at Clemson. Fiber, seed, and spinning tests are being made to provide data for computing linear regression coefficients and prediction equations, and making graphical representations of the findings. Total linear regression from 100 percent fluffy locks to 100 percent tight locks was as follows:

Lint percent turnout -- 7.6 percentage points, from 39.2 to 31.6 percent
Micronaire reading -- 1.11, from 3.59 to 2.48
Colorimeter reflectance, R_d -- 19.6, from 74.2 to 54.6
Colorimeter yellowness, +b -- 3.5, from 8.0 to 11.5
Grade equivalent, colorimeter -- from SLM to SGO yellow tinged

These results show trends in degradation of fiber quality in relation to the proportion of field degraded tight locks in the seed cotton. These data show close agreement with a preliminary scale of fiber quality for field degraded cotton which was developed last year.

Evaluation tests were made at Clemson for the fourth year on an experimental drum-type tight lock separator and an auger-type separator. Again this year, bale value increases by removing the tight locks from the cotton were less than $5 per bale. Measurements of fiber properties were found to be relatively insensitive to changes in tight lock content, particularly with the low incidence of tight locks in the cotton available during the development of this equipment. No further development and testing of the separators is planned; however, they will be retained on a standby basis in anticipation of seasons of higher field degradation, which have occurred in the past. The separators have been and will continue to be used to separate tight locks for setting up scales of fiber quality and spinning performance for cottons containing from 0 to 100 percent tight locks in 10 percent increments. This indirect approach should provide a better indication of the advisability of tight lock removal prior to ginning than comparison of

grade, staple, and fiber properties of uncontrolled lots of cotton processed with and without the lock separator.

Analysis of trash made at Clemson showed that bur size varied among varieties and seasons of growth and that sticks in all cottons analyzed ranged from 1 to 2 inches in length irrespective of type of harvest. The number of sticks in machine-picked cotton was about three times the amount found in hand-harvested material. Machine-stripped cotton contained eight to nine times the amount found in hand-harvested material.

D. Conveying

1. At Mesilla Park effort was concentrated on an air-jet conveyor system which shows considerable promise for adaptation to all materials handling problems in the gin in addition to seed cotton. Conveyor capacity rates for various air volumes at the horizontal and at various inclined positions were studied. The tests showed the air-jet conveyor to have potentially sufficient capacity to meet the requirements of modern high-capacity plants. Further, the tests showed the air-jet conveyor to be much more efficient than conventional methods.

E. Gin Stands

1. Saw Gins

Research at Stoneville shows that the use of reduced diameter saws is poor economy in today's high-capacity gins. A reduction of 1/16-inch in saw diameter due to repunching resulted in a 10 percent reduction in ginning rate, a 10 percent increase in energy requirements, and a 1 percent increase in seed linters content.

A device which recently came on the market to change the profile of a low-capacity gin stand roll box was tested at Stoneville. The device gave an increase in capacity of 16.4 percent in a 12-inch 80-saw stand. Significant increases in power and energy requirements and residual linters were noted when the device was used. There was a very slight reduction in upper quartile and mean fiber lengths associated with the use of the device.

2. Roller Gins

At Mesilla Park a conventional roller gin feeder was modified to eliminate the feeder apron and to allow the final doffer brush in the feeder to present the cotton in a single lock form directly to the ginning point of the gin stand. This modification eliminates the difficulty experienced with static on the lint slide, gives a more even feed of cotton to the gin, thus increasing capacity and reducing the amount of seed cotton which must be reclaimed from the seed system. Because of a more even distribution of cotton on the roll, it ran cooler which prolonged its life and thereby reduced maintenance cost.

Tests of pressure of the stationary knife against the ginning roll in combination with roll speed showed that capacity was increased from 12.1 to 19.4 pounds per inch of roll per hour for Pima and from 8.8 to 12.8 for Acala 1517 when roll speed was increased from 80 to 100 r.p.m. and knife pressure increased from 75 to 110 pounds per square inch of gage pressure. The gin roller surface temperature ranged from 88° F. at 80 r.p.m. to 132° F. for 100 r.p.m.

Studies of the effect of roller speed and rotary knife pressure showed that with Pima cotton 9.0 pounds of lint per inch of roller per hour was obtained at 80 r.p.m. and 75 p.s.i. gage pressure on the knife as compared to 25.3 pounds per inch per hour at 140 p.s.i. knife pressure. Acala 1517 cotton was ginned at a rate of 6.4 pounds per inch per hour at 50 r.p.m. and 85 p.s.i. gage pressure as opposed to 18.8 pounds at a roll speed of 160 r.p.m. and 110 p.s.i. gage pressure. The high rates correspond to two bales of Pima per hour and one and one-half bales of Acala 1517 per hour for a gin stand having a standard width of 40 inches.

At Mesilla Park studies were made of adjustments of a new type high capacity roller gin stand using Acala 1517 cotton. Three mechanical adjustments were studied: (1) The clearance between the rotary and stationary knives; (2) the position of the rotary knife parallel to the stationary knife; and (3) the angular position of the stationary knife with respect to the roller surface. It was found that the knife-to-knife clearance must be maintained between 0.030 and 0.040 inch. Increasing the clearance caused a decrease in ginning rate and decreasing the clearance resulted in the possibility of collision between and breakage of the knives. Changing the rotary knife position parallel to the stationary knife had little effect over the range studied. The angular position of the stationary knife with respect to the roller surface was studied over only a small range, presently limited by the construction of the gin stand. Increasing the tilt of the knife away from the roller surface increased ginning rate, produced less neps in the ginned lint and ginned less linters from the seed, all desirable changes. These studies will be continued using both the McCarthy and the new high-speed rotary-knife roller gin stands.

F. Gin Performance and Cotton Quality

1. Power requirements and efficiency. In cooperation with the Economics Research Service, power and energy data were collected at 11 high-capacity gin plants in California and West Texas. Power requirements for operating the California plants averaged 650.8 horsepower. The Texas plants required 638.5 horsepower. Energy consumption was calculated to be 48.3 and 45.9 kw.-hr. per bale for the California and West Texas gins, respectively. Slightly higher connected loads were noted for the West Texas plants, while idle loads were slightly higher for the California plants.

Studies in the Mississippi Delta area showed that per bale energy requirements for pressing ranged from .38 to .52 kw.-hr. per bale. The studies also showed that mechanical tramping is by far more economical than hydraulic.

At Clemson efficiency studies were conducted at six commercial gins in the Coastal Plain area of South Carolina to study and evaluate operational efficiency of equipment and techniques employed at commercial gins and power requirements for operating gin machinery. Five of the six were high-capacity plants, representing each of the five major gin machinery manufacturers. The sixth gin was an older style low-capacity plant.

Total connected electrical load ranged from 370 to 666 horsepower rated capacity from 6 to 14 bales per hour and electrical load per bale rated capacity from 41.1 to 63.3 horsepower. Electrical load per bale rated capacity, reflecting plant design efficiency, was highest at the low capacity plant.

Power consumption ranged from 33.8 to 70.8 kw.-hrs. per 500 pound gross weight bale.

Plant operational efficiency, ranging from 52 to 96 percent, was affected by practices utilized both within the gin and on the gin yard and by conditions existing at each gin. Some practices resulted from imposed conditions over which the ginner had little or no control.

Practices and conditions within the gin which contributed to idle operating time or resulted in a decreased ginning rate were the major factors adversely affecting plant operational efficiency. Plant efficiency was highest at those gins utilizing practices to minimize idle operating time.

The manner in which seed cotton was delivered to the gin imposed conditions which influenced gin yard practices. One-bale loads, seed cotton all or partially in sheets, and single axle trailers increased personnel requirements, created additional problems on the gin yard, and magnified the effects of inefficient practices within the gin. Generally, power consumption per bale increased as the amount of seed cotton in sheets and one-bale loads increased. Plant operational efficiency increased when practices, designed to minimize the effects of imposed conditions, were adopted.

Based on the results of this study, conclusions in the form of general recommendations for more efficient gin plant operation and reduction of power requirements were developed and published.

2. Quality evaluation. As a matter of routine all samples of lint ginned in connection with the research program at Mesilla Park are subjected to scanning with ultraviolet light and to relate any fluorescence to its cause and fiber quality irregularities.

At Mesilla Park two instruments for measuring tenacity of seed cotton were evaluated. A statistical analysis of over 1,200 measurements using a 1/8-inch spacer in the seed cotton clamps favored a modified Scott Tester over a modified Hunter Terminal Pull Tester.

Five experimental methods for rapidly determining the amount of linters in cottonseed as an index of ginning performance were investigated at Mesilla Park. Preliminary results show that a visual grading system may prove to be sufficiently accurate and of more practical value than other methods tested.

Studies at Mesilla Park as to how neps are formed showed that saw ginned samples averaged eight to nine neps while the roller ginned control averaged three to four. There was no statistical difference between the nep counts of cotton ginned at a saw speed of 300 and 600 r.p.m.

A survey of five high capacity and three conventional roller gins was made in the Mesilla Valley on both long staple and upland cotton. With each type cotton, the high capacity gins ginned at greater average rates than did the conventional gins; with upland, 5.43 vs. 2.22 lbs./in. roll/hr.; and with Pima, 6.66 vs. 3.68 lbs. The high capacity gins averaged very slightly more seedcoat fragments, but the fragments were reduced by mill-type lint cleaners. Cottonseed and fiber qualities were similar for the two types of gins; except array measurements showed the lint, both upland and Pima, from the high capacity gins had greater mean lengths and fewer short fibers than did the conventional roller gins.

Comparisions between methods of determining cottonseed moisture content were made at Mesilla Park. This work included experimental wire baskets versus conventional aluminum cups, with and without forced draft in the oven, and the times of 1 hour versus a weekend of storage of oven-dried samples in a desiccator. The conventional method with aluminum cups required much less time than the larger basket to obtain the same results. The forced draft in the oven was found to be necessary, and a weekend of storage of oven-dried samples in the desiccator did not affect the moisture content.

The problem of preginned lint lost in seed cotton cleaner waste was investigated at Mesilla Park. Lint recovered from this waste was subjected to no drying and excessive drying (300° F.) and excessive cleaning (bur machine and stick remover in addition to a 6-cylinder cleaner) while ginning Pima S-1 and S-2. The recovered preginned lint weighed only from 1 to 6 grams per 1,000 pounds of seed cotton. The preginned lint was inferior to the ginned lint in fiber length, length distribution, short fibers, micronaire, and strength. The measured small quantity and inferior qualities of the preginned lint make tham appear unimportant. No future research in this field is planned.

A wettability test under development at Clemson shows promise as a quick means for quality evaluation in ginning research. In this test a lint sample is dropped on the surface of an alcohol-water mixture and the submergence time is recorded.

Sample preparation has been found to be a critical factor and efforts this year were devoted to elimination of variation attributable to sample preparation techniques. Equipment was constructed for increasing compaction of the sample plug, thus resulting in a more uniform sample density.

At Clemson a Shirley Analyzer was used in destructive lint tests to magnify differences in fiber qualities which exist following ginning treatments, and then to correlate these differences with spinning performance.

Fiber qualities changed progressively during five passes through the Shirley Analyzer but the progression was not linear. Generally the first pass resulted in the greatest change, giving a hyperbolic curve.

Noteworthy trends and consistency were apparent in short fiber content and other length measurements; however, moisture regain, strength, and elongation measurements showed some inconsistency.

Correlation between yarn strength and fiber measurements was generally higher for micronaire and length measurements than for other fiber evaluations.

The effect of destructive lint tests on length measurements appears to be good indicators of yarn strength. Coefficients of correlation between yarn strength and Fibrograph UHML of lint which had been through the Shirley Analyzer 0, 1, 2, 3, 4, and 5 passes were 0.913, 0.953, 0.967, 0.975, 0.996, and 0.969, respectively.

Also at Clemson a photographer's exposure meter was used in developing an instrument evaluation of cotton fluorescence under ultraviolet light. Variations in intensity of fluorescence were detected with the meter in a test box under two long wave 4-watt lamps (3,660 angstrom units).

At Stoneville an effort was made to measure foreign matter components in lint cotton using one and two screens in the Shirley Analyzer trash pan. A 1/8-inch mesh screen was located 1/2 inch from the bottom of the trash pan and a 1/4-inch mesh screen was located 1-1/2 inches from the bottom. The tests show that for samples with a wide range of foreign matter, the material on the 1/4-inch screen and in the trash pan increased as the total waste increased, while the material on the 1/8-inch screen did not consistently increase as total waste increased. Use of the 1/4-inch screen in the trash pan is a valuable aid in picking up the lint and foreign matter for rerunning through the machine. On the basis of tests performed, two screens in the Shirley Analyzer trash pan can be used to analyze visible waste by size in lint samples.

In the tests at Stoneville aimed at improving the accuracy of the Shirley Analyzer results it was found that the average amount of second-pass visible waste on samples with a wide range of foreign matter was 10.5 percent of the first-pass total waste and 15 percent of the first-pass visible waste. When the foreign matter and lint in the trash pan are passed three times through the machine the total waste correction is 11.5 percent and the visible waste correction is changed to 14.5 percent. The accuracy of the one-pass method of testing is improved by using these correction percentages.

In other tests it was found that lint foreign matter testing time could be decreased from 5 to 3 minutes by increasing saw cylinder, feed roll, and condenser speeds 60 percent and the fan speed 6 percent.

Also at Stoneville a Shirley Analyzer procedure was worked out for determining the amount of seedcoat and funiculi in lint cotton. The test is much faster than the ASTM method but is not as accurate. However, it is suitable for screening samples. The procedure involves the use of 3 screens, 1/4-inch, 1/8-inch, and 1/16-inch mesh in the Shirley Analyzer trash pan and 10-gram test specimens. Testing time is 5 minutes as compared to 30 for the ASTM test procedure.

A formula was developed at Stoneville for obtaining cottonseed moisture percentages after 3 hours' drying. Calculated percentages did not differ from the regular 5-hour drying method percentages more than those found for two specimens taken from the sample container and tested by the regular 5-hour method.

The Mesilla Park Fiber Sorter gave good results when the data from 48 ginning test samples were compared with long and short fiber measurements made with the Suter-Webb Sorter.

In an effort to develop a rapid method for determining the amount of short fibers in a lint sample, tests were made at Stoneville using compressed air. Results closest to those from the standard array procedure were obtained using two 6-inch vise grips with a space of 7/16-inch between the vise grips clamping the fiber and an air pressure of 80 p.s.i. with a nozzle held 1/2 inch from the fiber. Averages for three tests on each of three check samples were not as good as desired, but more tests with changes in clamp holding surfaces and nozzle dimensions should give more accurate values.

The ASTM Differential Dye Test was found to be unsuitable for general use as an indicator of gin damage to cotton.

Tests at Stoneville show that a Ginning Laboratory designed, 3-level, constant-humidity cabinet was found to be an excellent tool for providing test specimens of highly uniform moisture content. A determination of equilibrium moisture content at 5 r.h. levels on lint preconditioned wet and preconditioned dry showed that similar cottons of different histories

can differ in equilibrium moisture content by as much as 1-1/2 percentage points at Mid-South ambient atmospheric conditions and at standard atmosphere for testing. Thus it is important that other methods of moisture determination (such as gravimetric) be used when correlating fiber properties to fiber moisture content.

At Mesilla Park small lots of Acala 4-42 and Pima S-2 seed cotton were treated to compare the effects of single-locking and mass-locking on ginning capacity and turnout. Single-locking was accomplished by separating individual seed cotton units by hand, with efforts to maintain the same original foreign matter and moisture contents. In the conditioned laboratory, 65 percent r.h. and 70° F., three replications of the upland were saw ginned and three replications of the Pima were roller ginned.

The Acala 4-42 ginned at a slightly faster rate when single-locked than when mass-locked (2.85 versus 2.65 lbs./saw/hr.), and the turnout was similar for the two treatments (39.0 and 38.8 respectively).

The Pima S-2 also ginned at a slightly faster rate when single-locked than when mass-locked (1.47 versus 1.41 lbs./in./hr.), and the turnout was practically the same for the two treatments (40.9 and 40.8, respectively). These preliminary tests, with single-locking of both upland and Pima, accomplished by hand to minimize changes in foreign matter and moisture contents, indicate that single-locking of seed cotton might be slightly superior to mass-locking in the effects on ginning capacity and turnout.

3. Effect of Cultural and Harvesting Practices. Tests at Mesilla Park show that spindle twists are a serious problem in roller ginning. Studies of what type of seed cotton cleaning principle was most efficient in removing them revealed that the "sling-off" principle of the stick machine showed the most promise and will be subjected to further tests.

In cooperative tests with the Cotton Mechanization group at Stoneville, six varieties of cotton with widely different stalk and boll characteristics were compared with respect to picking efficiency, trash content, response to cleaning and ginning, preharvest loss, and yield. Conditions were more uniform and picking efficiencies and yields were higher than in previous years. More trash was harvested with the Stoneville 7-A than the other five varieties. Delfos 9169 had the highest yield. However, there was no significant difference between the yields of Delfos 9169, Stoneville 7-A, D&PL Smoothleaf, and Lankart 57. Delfos 9169 had the highest picker efficiency. This was an excellent harvesting year and preharvest losses were very low.

There was some tendency shown toward a relationship between the average peak force required to remove a lock of cotton, the carpel angle, and the picker efficiency. Lankart 57 required the most force with an average of 162 grams, while Stoneville 7-A required the least force with an average of 70.7 grams.

Seed cotton lots representing three replications of the six varieties were cleaned and ginned in the Micro gin with a machinery arrangement normally recommended for machine-picked cotton in the Mid-South area.

There were no important differences in grade values even though Lankart 57 had a higher lint foreign matter content than the other five varieties. Acala 4-42 and Delfos 9169 had grade index values of 99.0 as compared to 100.0 for the other four varieties. The average staple and fibrograph span length of Delfos 9169 was higher than for the other five varieties. Fiber strength (zero gage) ranged from a high of 87.0 (1,000 p.s.i.) for Acala 4-42 down to 75.7 for Lankart 57 and Delfos 9169.

A second cooperative test at Stoneville involved topping rank-growing Stoneville 7-A cotton plants on three different dates (July 20, August 5, and August 20) and trimming lateral branches just as they began to lap in the row middle (July 24) had no effect on seed cotton yield, lint grade, staple length or picking efficiency. There was slightly less foreign matter in the machine-harvested seed cotton and lint from the topped and laterally trimmed plots than from the untreated plants, although no important differences were obtained among the topped and trimmed treatments. Boll rot loss was reduced slightly by early topping (July 20) in an area where the average boll rot loss was less than five percent. Although plant lodging, as well as boll rot, was not a problem in this area in 1964, it was observed that plants in the topped plots were more erect.

The harvested lots of seed cotton were processed in four replications in the Micro gin. The recommended ginning arrangement for machine-picked cotton was used.

Grade for all lots and treatments was Middling, and all cotton samples classed 1-1/16 inch in staple length.

Tests conducted at the Southeastern Cotton Ginning Research Laboratory in cooperation with Clemson University Agricultural Engineering Department indicate weed control practices affect lint grade and value.

Four field treatments were as follows:

1. Treflan-Mechanical
2. Treflan-Mechanical-Flame
3. Karmex-(applied in band) Mechanical-Flame
4. Herban-Dicryl DSMA-Flame

Visible waste in lint of treatment 4 was significantly greater than that of all other treatments and total waste in lint of treatment 4 was greater than that of treatment 2.

Wagon grass content of treatment 4 averaged 1.18 percent compared to less than 0.12 percent for other treatments. This grass content was reflected in grade reductions assessed all samples from treatment 4, one-half of which were reduced two full grades.

All treatments, except treatment 2, had at least one classers sample reduced in grade because of grass.

Grade index and per pound lint value of treatments 2 and 1, after reductions due to grass, were significantly higher than that of treatment 4.

Though not significant, lint from treatment 4 had the highest picker card waste and the lowest strength 1/8-inch gage, average break factor, 2.5 percent span length and color factors.

Results of all factors measured indicate that treatments 2 and 3 produced the most desirable results and treatment 4 the least desirable.

At Clemson a study was made to compare the ginning performance, fiber qualities, and spinning performance of spindle-picked and stripper-harvested cotton, and to evaluate seed cotton conditioning and cleaning treatments for processing cotton harvested by the two methods. This study was in cooperation with the pilot spinning plant and the mechanization group of ARS.

Returns per acre were $42.78 more for the stripper cotton than for the picker, based on gross value of the lint and seed. Yields per acre were 2.13 bales with the stripper and 1.76 bales with the picker. Harvesting and ginning costs were not specifically evaluated. Grade index averaged 94 for the picker and 83 for the stripper, with the lower value for the stripper due primarily to grass content. Staple lengths were practically the same, averaging 33.7 (32nds inch) for the picker and 34.0 for the stripper.

Other significant comparisons between the picker and stripper, respectively, were: Wagon sample trash content, 3.6 percent versus 25.5 percent; feeder sample trash content 0.9 percent versus 4.1 percent; lint foreign matter, 3.2 percent versus 4.9 percent; colorimeter yellowness, 8.4 versus 7.7; CCC price per pound, 30.29 cents versus 27.92 cents; ginning rate, 8.5 lbs./saw/hr. versus 6.7; and total trash removal per bale, 72.5 lbs. versus 534.5 lbs.

Ginning treatments included three seed cotton cleaning arrangements: (1) Conventional setup for machine-picked cotton, (2) same machinery but with stick and green leaf machine placed following first drier, and (3) same as No. 1, but with stick machine following last cleaner. All cotton was processed through two lint cleaners, and driers were set to maintain 6 percent lint moisture at the ginning point. In analyzing the ginning treatments, the only significant difference was in lint value. The price per pound averaged 43 points less for the setup with the stick machine placed last when compared with the average of the other two treatments.

Tests were made at Mesilla Park of the ginning characteristics of various new strains of cotton being developed for various parts of the Southwest.

Completed measurements on the 1963 crop of five upland strains showed that Strains Nos. 6612 and 8229 compared at least favorably in capacity, turnout, length and all other qualities with the standard variety, 1517D, grown in that area. Generally, with this group of strains, the higher ginning capacities are associated with lower tenacity, fewer cottonseed linters, fewer short fibers, and greater seed index. Number 6612 was released as 1517V for production on Verticillium wilt infested soils.

The five strains in the 1964 crop included Strain No. 4447, formerly Hopi Acala, and recently released for production in Arizona as Hopicala. Since it does not have quite the staple length of 1517D, it was not released for production in New Mexico and Texas. A few small tests show that Hopicala gins at about the same capacity as 1517D. Quality measurements for tenacity, cottonseed, and fibers are not complete. The seeds of Hopicala appear relatively fuzzy. No major problem is anticipated in ginning Hopicala, but present plans are to continue research with this new variety, both with small lots of cotton in the laboratory and with observations and sampling of commercial gins in Arizona.

Completed measurements for the 1963 crop of four Pima strains (S-1, S-2, E1044, and P14) showed that E1044 had ginning and quality characteristics similar or only slightly better than the old S-1, but the E1044 had longer fibers. Incompleted measurements for the 1964 crop of six strains at two locations showed again that the E1044 ginned at a rate only slightly better than S-1, and was surpassed by the other strains at both locations (Tempe and Safford). As a result of the longer fibers of the E1044 than either S-1 or S-2, this new strain is being increased for possible release in locations of high elevation such as the Mesilla and El Paso Valleys. The cooperating breeder is considering the release of more than one strain for the different elevations in the areas of Pima production. The 1964 strains include P15 and P17, either of which might be released for production at the lower elevations. These two strains ginned at better rates than did the E1044 or S-1, but not quite as well as S-2.

Among the completed measurements of the 1963 strains, greater ginning capacity appears to be associated with greater turnout, lower tenacity, and lower cottonseed linters contents.

G. Lint Cleaning

1. A study at Stoneville of the effect of lint cleaning on cotton quality at various lint moisture levels indicated that increases in the fiber moisture content at lint cleaning decreases the cleaning efficiency of the lint cleaners, and increasing the number of lint cleaners decreases the foreign matter content of the lint in a curvilinear relationship.

Increases in the classers grade index is directly related to decreases in the fiber moisture content at lint cleaning and to the number of lint cleaners, while increasing the fiber moisture content and decreasing the lint cleaner stages gave an increase in the classers staple length. For maximum foreign matter removal commensurate with minimized changes in classers staple length, a moisture range of about 7.0 percent gave the best results.

Decreases in the 2.5 percent span length and 50 percent span length are related to decreases in the fiber moisture content at lint cleaning and to increases in number of lint cleaners. Fifty percent span length data show an unacceptable amount of fiber breakage with three and four lint cleaners at any moisture level, and show an unacceptable amount of breakage with one and two lint cleaners at fiber moisture of five percent and below. Number of neps per 100 square inch of web increased with added lint cleaners, but showed essentially no difference due to changes in fiber moisture content.

H. Packaging

1. Two experimental packaging materials were evaluated at Stoneville for the National Cotton Council.

Assistance was given in developing USDA Standard for Jute Bagging. These standards have been published in the Federal Register.

Studies underway on new packaging methods at Stoneville indicate that a round "picker lap type" bale may be mechanically feasible for gins. Preliminary tests indicate that if such a packaging system can be developed labor may be reduced 50 percent and power 80 percent.

I. Cottonseed

1. A device initially designed in 1962 for the removal of cockleburs from cottonseed was fabricated and subjected to experimental testing at Stoneville.

First-cut and second-cut cottonseed and corresponding first-cut and second-cut cockleburs were used, with the machine operated at various angles of incline, feeds, speeds, etc.

It was found best to use first-cut delinted seed in the machine, and with the best selected operating conditions the device proved to be effective to the extent of removing 50 percent of cockleburs from the first-cut cottonseed. While this is a help, it is not considered good enough to justify an enthusiastic recommendation of the device for use in the cottonseed industry.

Investigations designed to determine the degree to which cottonseed are mechanically damaged during the ginning process were carried on by the Stoneville Laboratory. These studies were conducted in five commercial gin plants in the Imperial Valley of California during the 1964 ginning season. Results of these tests indicate an average of 10.7 percent damage resulting from both harvesting and ginning. The ginning process accounted for 5.7 percent of this damage. Test data also indicated that gin stand damage will also increase with some of the new type high-capacity gin stands. In general, increased gin stand damage was also noted at higher seed moisture contents and seed indexes. Tests are now being made to determine the effect of mechanical damage on seed germination.

Studies were also made to study the effect of varying ginning rates on cottonseed quality. Results of these studies conducted on a new type, high-capacity gin stand indicated that increases in ginning rates will cause accompanying increases in seed damage. For ginning rates ranging from approximately 10 to 23 pounds of lint per saw per hour, seed damage increased from 19 to 33 percent. Average germination results, from the three test series involving five bales each of early, mid, and late season cottons, indicated a 3.5 percent reduction in germination resulting from ginning.

Increases in abnormal and secondary root seedlings were also noted as a result of gin processing. The presence of seedcoat fragments in lint samples also increased as ginning rates were increased.

Tests at Clemson also showed that the average seed damage generally was greater in high-capacity gins than in the control gin.

Seed germination values were unusually low throughout the state this year and seed quality values in this study were inconsistent as well. For the control gin, the percent abnormals counted in the germination lots were slightly higher than the average for the high-capacity gins. Seedcoat fragments were also higher for the control gin.

The percent residual linters averaged higher for the high-capacity gin than for the control gin.

J. Waste Collection and Disposal

1. Tests were made by the Mesilla Park Laboratory to check the design of high-capacity inline air filters to handle large volumes of air. One was designed to filter 20,000 cubic feet of air per minute and was installed at a local gin plant on a large battery-type condenser exhaust. Another filter was installed at a gin plant near Lubbock, Texas. It was designed to handle 10,000 cubic feet of air per minute. Both filter units performed satisfactorily throughout the entire ginning season. These tests showed that the large inline air filters for battery-type condenser exhausts could be properly sized by using the Laboratory's design procedure.

A large centralized air filtering system was installed at the Dona Ana Gin Company's roller gin at Dona Ana, New Mexico. This large filter unit, sized to handle 33,000 cubic feet of air per minute, was placed in the end wall of a 10-foot by 20-foot dust house attached to the main gin building. Four condenser exhausts discharged dust and lint laden air into the dust house. This polluted air was then cleaned as it passed through the wall filter on its way to the outside. While mechanical difficulties prevented a complete season's testing of the system, it did operate long enough to show that the centralized filtering concept was feasible but that better mechanical design was needed. This type of filtering system would be particularly attractive when a number of exhausts exit from the gin building at a central location.

Studies at Clemson indicate that wet operation of an experimental inertial separation chamber was more effective in removal of dust and other particulate matter than was dry operation.

Air from the unloading separator was exhausted into the chamber to provide a source of dust-laden air relatively free of large trash particles. Chamber design limited flow of air to approximately 7.0 feet per second. Only the larger and heavier trash particles were removed in the chamber during dry operation and considerable dust and fly lint was observed near the chamber exhaust.

For wet operation nine spray nozzles, located in the first two chamber sections, injected approximately 70 gallons of water per hour at 80 p.s.i. Only occasional particles of trash were observed emerging from the chamber exhaust during wet operation. Dust concentration at chamber exhaust while operating dry averaged 0.1412 and 0.6550 grams/1,000 feet for late season machine-picked and machine-stripped cottons respectively. With addition of water spray to the chamber, dust concentration was reduced to 0.0379 and 0.1811 grams/1,000 cubic feet for late season machine-picked and machine-stripped cottons respectively. Wet operation decreased dust concentrations by approximately 73 percent.

Tests at Stoneville show that lint fly from the exhaust of low-pressure condenser fans can be eliminated at the condenser by using fine meshed screen or perforated sheet metal for drum covering. This can be done without detrimental effect on the quality of the lint.

The Stoneville Laboratory and the Economic Research Service initiated cooperative studies aimed at the development and evaluation of a new and better method for reclaiming and cleaning gin-loss cotton. These studies resulted in the development of a machine for reclaiming usable fibers from gin-loss material.

Test evaluations of the machine indicated that approximately 72 percent of the usable fibers present in gin-loss cotton could be reclaimed with only one processing. Average cleaning efficiency for the reclaiming device was 84.3

percent. Tests also indicated that length distribution of the gin-loss fibers was slightly improved as a result of processing. Spinning tests indicated that it is feasible to spin a mix consisting of 100 percent reclaimed fibers. Although manufacturing waste was high and yarn strength and appearance relatively low when only reclaimed fibers were used, they should perform satisfactorily in mixes used to manufacture certain low-count yarns and fabric constructions.

Buyers offered an average of 1.5 cents per pound for gin-loss cotton before processing, and 6.67 cents per pound after processing. Based on these prices, and after adjustment for weight loss bale value was increased over $5 per bale by one pass through the reclaiming facility. Under current price relationships and market outlets, it is not profitable to pass gin-loss cotton through the reclaimer more than one time.

Feasibility of blending reclaimed gin-loss fibers into the bale from which they originated was also investigated. At blending rates averaging 8.5 pounds of reclaimed fiber per bale, no important differences were noted in grade, staple length, fiber properties, and spinning performance between blended and non-blended cottons. Based on current market prices, bale value was increased by $2.69 as a result of the blending operation.

Based on results obtained from these studies, reclaiming of gin-loss cotton by methods described in this report is an entirely feasible and profitable practice for use in cotton ginning systems. The increase in overall quality of gin-loss cotton resulting from the reclaiming process would make the material much more competitive in the cotton waste industry. No definite conclusions were reached regarding the blending of gin-loss fibers back into a gin bale due to the limited scope of these studies. Large scale spinning tests are planned for further evaluation.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Seed Cotton Handling and Storage

Baker, Roy V., and Stedronsky, Victor L. 1965. An improved unloading system for gins. The Cotton Gin and Oil Mill Press. Vol. 66, No. 7, pp. 50-51, March 27.

Seed Cotton Conditioning

Garner, Warren E., and Mullikin, Robert A. 1964. Effect of certain drying treatments in ginning on fiber properties and spinning performance of Southeastern cotton, crop of 1960. Production Research Report No. 85. December.

Moore, V. P., and Griffin, A. C. 1964. The relationship of moisture to cotton quality preservation at gins. ARS 42-105. December.

Seed Cotton Cleaning

Franks, G. N., and Shaw, C. S. 1964. A seed cotton cleaner without moving parts. ARS 42-106. December.

Gin Stands

Moore, V. P., and Watson, Harold. 1964. A critical look at huller fronts. The Cotton Gin and Oil Mill Press. June.

Gin Performance and Cotton Quality

Chapman, W. E. Jr., and Stedronsky, V. L. 1965. Comparative performance of saw and roller gins on Acala and Pima cottons. Marketing Research Report No. 695. June.

Cocke, J. B. 1965. Reducing power costs in Southeastern gins. The Cotton Gin and Oil Mill Press. February.

LaFerney, Preston E., Mullikin, Robert A., and Chapman, Walter E. 1965. Effects of defoliation, harvesting, and ginning practices on micronaire reading, fiber properties, manufacturing performance, and product quality of El Paso area cotton, season 1960-61. Marketing Research Report No. 690. January.

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Watson, Harold. 1964. Efficient gin plant operation. The Cotton Digest. September.

Watson, Harold, and Looney, Z. M. 1964. Start at the starter switch for efficient gin operation. The Cotton Gin and Oil Mill Press. November.

Wilmont, Charles A., and Alberson, David M. 1964. Effects of oversized motors on power costs in ginning cotton. ERS No. 203. November.

Lint Cleaning

1964. Take a safety brake (a brake for lint cleaners). The Cotton Gin and Oil Mill Press. September.

Cottonseed

Watson, Harold, and Helmer, James D. 1964. Cottonseed quality as affected by the ginning process--a progress report. USDA, ARS 42-107. December.

Waste Collection and Disposal

Alberson, David M., and Baker, Roy V. 1964. An inline air filter for collecting cotton gin air pollutants. USDA, ARS 42-103. September.

McCaskill, O. L., and Moore, V. P. 1964. Elimination of lint fly. The Cotton Gin and Oil Mill Press. October.

AREA NO. 7. STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Problem. The magnitude and scope of the crop and machinery storage problem is evidenced by the vast quantities of crops and other materials handled and stored on the farm. Annually on the farm: (1) Five billion bushels of corn, wheat, and other grains are harvested and stored, of which nearly one billion is carried over from the preceding year; (2) 208 million tons of hay and silage are processed and stored; (3) nearly 2.5 million bushels of apples and pears and 34 million hundred-weight of potatoes and sweet potatoes are held for food, feed, and seed; (4) other large quantities of fruits and vegetables are held for temporary storage pending marketing; and (5) large amounts of fertilizers and feeds are purchased and held in storage pending use. An aggregate total of more than seven million tractors, combines, corn pickers, and other expensive farm machines need storage and repair buildings to maintain operating efficiency.

Farming methods are continually changing, requiring new information to be developed to keep storage structure design abreast of the cropping practices. For example, crops are being harvested, handled, and stored in new forms such as high moisture shelled corn, wafered forage, and low moisture silage.

Plant growth structures can represent investments ranging from a few hundred to several million dollars depending on their nature and scale. Controlled environment growth chambers range from $1000 to $50,000, controlled environment greenhouses from $2000 to $700,000, and phytotrons from $400,000 to $5,000,000. During the last four years, the USDA has spent about $500,000 per year for growth chambers. No overall expenditure figures are available.

The 1959 census showed 227 million square feet of commercial greenhouse area in the United States. Of this area, 83% is used for florist crops, 4% for nursery crops, and 13% for vegetable crops. Greenhouse produced crops equal 2% of all farm products sold.

Recent experience of plant and other scientists concerned with use of plant growth chambers indicates a general inability to closely maintain desired environmental conditions and a lack of means for measuring conditions actually maintained in these units. There is urgent need to develop engineering design criteria for constructing and equipping chambers that will reliably provide and maintain desired thermal, lighting, and other environment over a wide range of experimental conditions. Design criteria for automatically maintaining scheduled environments are needed also for greenhouses and other production type plant growth structures.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures.

A. Crop Storage Structures (silos and bins). Research is cooperative with Animal Husbandry Research Division, ARS; with Cooperative Regional Research Project NE-13, "Determination of the Basic Job Requirement of Machinery for Harvesting and Storage of Grass Silage", at Beltsville, Maryland; and with the Agricultural Experiment Stations at Athens, Georgia; East Lansing, Michigan; and Ames, Iowa.

B. Plant Growth Structures (environmental chambers and greenhouses). Research at Beltsville, Maryland, is cooperative with Crops Research Division, ARS.

C. Plan Development. Typical plans for crop structures and related equipment are developed at Beltsville in cooperation with the regional committees representing all State Experiment Stations and Extension Services.

The Federal effort in this research area totals 3.2 professional man-years. Of this number 1.9 are devoted to crop storage structures; 1.0 to plant growth structures; 0.1 to plan development; and 0.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment, and service facilities which are required for such production has necessitated a continuing program of research at the State Agricultural Experiment Stations.

The current broad scale program is concerned with conditioning and storages for high moisture grains; curing, bulk handling, and storage for onions; curing and storage sheds for tobacco; structural characteristics, wall pressures, design and construction of silos; Irish potato and sweet potato plant production facilities and storages; controlled atmosphere storages and construction methods; design for machinery sheds and farm service buildings; and designs and construction of plant growth chambers and plastic greenhouses.

Much of this research activity is cooperative with the Department.

A total of 10.5 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Crop storage structures

1. Silo design criteria. Determination of forage density in normal storage conditions, using a radioisotope, continued at Beltsville, Maryland. This year's work was aimed at finding effects of length of chopped alfalfa on stored silage density. Measurements were more precise than in previous years. Chopped alfalfa in chop lengths averaging 1.34 and 0.80 inches was loaded in a silo with the two chop lengths in alternate layers. The long chopped layers averaged 95% and 91% as dense as the short chopped layers at 1.8 and 21 days after loading, respectively. There were indications that settling proceeded unevenly around the silo circumference. It is planned to determine density in a silo loaded by typical farm procedure next year.

At Athens, Georgia, research continued on measurements of the gaseous transfer rate of silo construction materials. Effort during the year was on measuring the flow of oxygen through concrete silo walls. Flow rates through basic silo staves were determined under conditions of equal total pressure; hence, flow was caused by a pressure gradient across the concrete sample. Treatments in the study involved coatings of plaster, latex paint, and a special polystyrene paint. Results indicate that oxygen diffusion through silo walls could be greatly reduced by the application of an inexpensive coating which is relatively impervious to oxygen flow. This project was actively conducted for only nine months this report year. The work is being phased out at this location and no additional activity is planned.

On studies of pressures in large tower silos, at East Lansing, Michigan, no reportable progress was made.

2. Heavily wilted silage storage. In studies at Beltsville, Maryland, dry matter density of heavily wilted alfalfa in tower silos was 15% less at 64% dry matter than at 44%, which represents a decrease of silo capacity and more difficulty in sealing with low moisture silage. This, plus the chance of weather damage during heavy wilting, is an important deterrent to using very dry silage. Visible spoilage in storage was found to have no simple relation to total storage losses. Feed dry matter recoveries from 3 farm size silos were 89%, 90%, 91% from respective average dry matters of 44%, 58%, 64%, in contrast to a similar test last year from which recoveries were inversely related to dryness. Further trials will be run to reconcile these findings. A trial of making heavily wilted orchardgrass silage in a bunker during adverse weather produced silage which heated for 25 days and yielded only 72% recovery from storage, which shows the disadvantage of attempting heavy wilting during poor drying weather. Plans for next year are a comparison of 2 chop lengths of wilted alfalfa for storage efficiency and handling problems.

3. Bunker silo pressures. No reportable progress was made on the study of pressures on bunker silo walls at Beltsville, Maryland, due to the scarcity of forage at Beltsville. Work is expected to continue whenever full loads of critical crops are available for the test silos.

4. Hay wafer storage. No work was done on the hay wafer storage project at Beltsville, Maryland, during the reporting year. Consideration is being given to resuming this work at a later date.

5. High moisture shelled corn storage. At Ames, Iowa, no additional field work was done on storage of high moisture shelled corn. Data obtained in previous studies were analyzed for the effects of gaseous (oxygen-carbon dioxide) environment on rate of growth of microorganisms such as molds, bacteria, and yeasts. This rate of growth is a function of the moisture content, temperature, and available food or physical damage of the kernel coat and also may be considered as an oxidation resulting in production of carbon dioxide. Since the evolution of carbon dioxide can be readily measured, it can be used as an index of deterioration.

Molds, coliform bacteria, mesophilic aerobic bacteria and yeasts had been enumerated at intervals during ensiling. The numbers of aerobic bacteria were similar in structures containing different concentrations of gas and held at different temperatures. Coliform bacteria could not be detected after 10 days of ensiling. Mold numbers were relatively low, but were important in the deterioration of corn at the surface of the silos. Yeast and bacterial numbers increased rapidly following an initial aeration period, but no increase was observed after a second aeration series. Lack of a growth response to the second aeration series is believed related to the depletion of an assimilable carbon source. Yeasts were preeminent in proper preservation of high moisture corn.

B. Plant growth structures

1. Environmental chambers. At Beltsville, Maryland, studies to develop improved design criteria for environmental chambers were continued.

The far-red light source, developed in 1962 and improved in 1963, has been used frequently since then in research by plant physiologists. Some of the experimental results with the improved source indicate that infra-red (heat) radiation affects the research results obtained from far-red treatment.

The motion meter which was developed in 1963 by adapting a commercial angle transducer has been improved by addition of another transducer to permit simultaneous recording of both horizontal and vertical motion. An electric laboratory jack and optical relay have been added to raise the transducer as the plant grows. Movements as small as .005 inches can be detected with this equipment.

Experiments to determine the effects of different lamps on growth of plants were continued. Pinto beans (bush) under far-red light treatment developed into pole type beans with elongated internodes. This light caused barley to flower and set seed, suiting it it use as a positive indicator of light treatment. A small leak (much less than full moon light) of incandescent light during the first few minutes of darkness caused the barley plants to flower the same as plants treated to high intensity incandescent light just before darkness.

Studies of the reactions of annual flower plants to air enriched with CO_2 gas were initiated. Plants treated for 10 days and then grown out in the greenhouse remained more developed and quicker to flower and set seed than to control plants.

2. Greenhouses. No reportable progress was made in research on greenhouses.

C. Plan development

At Beltsville, Maryland, cooperative work with the Crops Research Division resulted in the development of Plan No. 5971, Hotbed and Propagating Frame, for the Cooperative Farm Building Plan Exchange. This plastic covered frame is portable, inexpensive, and flexible in operation for either starting plants early in the spring or rooting cuttings during the summer. It is a practical help in carrying forward the program of beautification.

Preliminary drawings have been made on a basement type plant growth chamber for the home owner.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Crop Storage Studies

Hendrix, A. T. and Miller, W. J. 1964. Horizontal silos - their construction, filling, use, and care. Georgia Agricultural Experimental Station Bulletin. NS113. May.

Wilkins, D. E., James, P. E. and Menear, J. R. 1964. Silage density measured by gamma energy attenuation. Transactions of American Society of Agricultural Engineers. 7:3:213. 1964.

Plant Growth Structures

Downs, R. J., Norris, K. H., Bailey, W. A., and Klueter, H. H. 1964. Measurement of Irradiance for Plant Growth and Development. Proceedings of the American Society for Horticultural Science. Vol. 85, 1964. pp. 663-671.

Plan Development

Agricultural Engineering Research Division. 1965. Hotbed and propagating frame. (Exchange Plan No. 5971) Miscellaneous Publication No. 986. February, 1965.

Wester, R. E. and Edgerley, W. E. 1965. A portable frame you can build--coldframe hotbed propagating frame. Horticulture 43:24, 25. March 1965.

AREA NO. 8. RURAL DWELLINGS

Problem. The 1960 Census of Housing indicates that although about 500,000 new farmhouses were built between 1950 and 1960, rural housing as a whole continues to be older than and inferior to urban housing in condition and value of buildings and in availability of plumbing, heating, and labor-saving equipment. Large numbers of houses outside of cities and towns remain without the conveniences and comfort features of typical urban homes.

Housing costs are still a major obstacle for farm families that wish to make improvements for themselves or to furnish better housing to attract and hold qualified and reliable tenants or workers, either full-time or seasonal. Costs are also a problem for the rural non-farm family. Continuing research is needed on ways to reduce costs through better use of space and improved application of old and new materials and use of more efficient construction methods. The stepped-up Farmers Home Administration program of rural housing loans needs research support to provide designs that will meet modern housing standards at moderate cost and be sound and desirable security for 30-year government loans. Further research is also needed on design and equipment of houses for improved control of temperature, air movement and noise, and economy of operation and maintenance.

With the rapid increase of the non-farm population in rural areas outside of villages, including many elderly and retired people, more attention should be given to their housing. People who have vegetable gardens and garden equipment to store, and who live on small acreages, drawing water from wells and using septic tank sewage disposal systems, have housing problems similar to those of farmers, and the housing research of the Department is applicable to them. Engineering research on design of equipment for the senior citizen is also needed.

Programs for bringing in foreign agricultural workers to supply the short term peak labor needs associated with many of our farm crops, particularly fruits and vegetables, are expiring. There is increased concern for the adequate and sanitary housing of domestic seasonal and migratory farm workers at reasonable costs. In view of this, there is need for research to develop design criteria for improved housing for these workers, particularly where the term of occupancy is short -- 2 to 4 weeks per year.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans and planning guides for rural dwellings of all types. A program of evaluation and development of construction plans and utilization of low-

cost housing for seasonal migratory farm workers was initiated for the U. S. Public Health Service under a reimbursable agreement dated March 22, 1965.

A. Design Criteria for Comfort, Health, and Safety. Research at Athens, Georgia, on determination and evaluation of thermal and sound effects of soft window and floor coverings, is in cooperation with the Georgia Agricultural Experiment Station. Development of planning aids at Athens, Georgia, is cooperative with the Georgia Station and at Beltsville, Maryland, with the Clothing and Housing Research Division, ARS.

B. Materials and Construction. Five experimental expansible houses at the Agricultural Research Center, Beltsville, Maryland, are under continuing evaluation of design, temperature control features and occupant reaction in cooperation with CH, ARS. An experimental structure for developing and evaluating low-cost floor deck and slab construction is located at Plant Industry Station, Beltsville, Maryland. A prototype low-cost house was constructed at Charles Town, West Virginia, to evaluate new design features. Foundation construction suitable for expansive clay soils has been under study at State College, Mississippi, in cooperation with the Mississippi Agricultural Experiment Station.

C. Systems for Environmental Control. A study to determine the optimum arrangement for an attic fan to reduce summer temperatures economically is underway at Athens, Georgia, in cooperation with the Georgia Station. An experimental, low-cost, plenum floor warm air heating system is being evaluated in one of the expansible houses at the Agricultural Research Center, Beltsville, Maryland.

D. Farmhouse Design Development. Architectural design and preparation of farmhouse plans for the Cooperative Farm Building Plan Exchange and related publications are carried on at Beltsville, Maryland, in cooperation with CH, ARS, and the Federal Extension Service. The State Agricultural Colleges cooperate through Regional Committees in establishing housing requirements and making the plans available to the public. Farmers Home Administration consults on requirements and makes plans available to its clients.

The Federal effort in this research area totals 6.0 professional man-years. Of this number, 1.2 are devoted to design criteria for comfort, health, and safety; 1.2 to studies of materials and construction; 0.5 to systems for environmental control; 2.6 to development and preparation of improved farmhouse designs; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Although research in this area in past years has been most active in the State Agricultural Experiment Stations, investigation during this reporting period has been most limited by the agricultural engineers.

Leadership of programs of study has, for the most part, shifted to home economics with agricultural engineers providing largely consultation service.

A total of 0.2 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Design criteria for comfort, health and safety.

1. Thermal control. The laboratory study of the effect of soft window and floor coverings on heat transfer and environmental factors of dry bulb temperature, radiation, and air motion is continuing at Athens. One useable test has been completed. Results indicated the necessity for accurate calibration of the test equipment used in obtaining the heat transfer data. Several more tests will be required to obtain adequate data for accurate computation of heat balance with window coverings in place. An extended series of tests will be run to determine the effect of various types of drapes, curtains, and floor coverings. Tight window closures, esthetically acceptable, will be devised and tested to develop ways of utilizing the insulating value of the air space between the window glass and covering. Their effectiveness will be tested with different types of windows.

2. Noise control. The laboratory study at Athens of the effect of soft window and floor coverings in reducing noise levels in rural homes is progressing. Sound level data were recorded over 24-hour periods in kitchens, kitchen-family rooms, and kitchen-laundry rooms of 20 Athens' area homes. The highest average decibel (db) level within a one-hour period occurred between 7 a.m. and 8 a.m. and from 9 a.m. to 12 noon in 10 of the houses and from both 12 noon to 2 p.m. and 5 p.m. to 9 p.m. in the other 10. Among the 20 houses, the highest average decibel levels ranged from 72 to 84 db. The lowest average decibel levels ranged from 60 to 76 db. Decibel levels in the 20 houses ranged from 36 db at 8000 cps to 90 db at 125 cps. In 15 out of the 20 homes the maximum representative sound levels occurred at frequencies below 125 cps.

The reverberation room for measuring sound absorption coefficients of various floor and window covering materials and arrangements has been completely equipped for summer and winter temperature control. Additional equipment has been incorporated into the sound measuring system to achieve more accurate readings. Diffusion panels have been installed and an extended series of tests completed to determine the size, number, and position of these panels, the position of microphones and the size of carpet sample needed to obtain optimum results. Preliminary tests were run on 11 carpets. Six statistical analyses were made comparing different types of fibers, pile weights, heights, and gauges. Highly significant differences were found by means of analysis of variance of rates of decay of sound pressure levels between fiber weights, between decibel levels, among frequencies, and between carpet treatment and no treatment for Acrilan

and for staple nylon carpets. The difference between fiber weights was not significant for nylon and the difference between Acrilan and wool fiber contents was not significant for a similar pile weight, height, and gauge and for similar construction. Some interactions of the various factors in the several tests were also significant or highly significant.

An extended series of tests are now underway in which various types of underlays will be used with the various carpet materials. Additional carpets are being obtained to provide a better comparison of pile weights, heights, gauges, and type of construction.

3. Planning aids. Work has progressed slowly on preparation and publication of the planning aids at Beltsville, Maryland, and at Athens, Georgia. These aids are in various stages of preparation, but completion has been hampered because of the heavy work load of staff members. Aids expected to be completed next year include: (1) Summer Cooling for the Farmhouse, (2) Insulation, (3) Choice of Siding, (4) How to Keep Basements Dry and (5) Framing. Manuscripts have been completed for "Control of Direct Sunlight for Comfort" and "Work Rooms". The latter was developed in cooperation with CHRD, as was "Laundry Areas", published in August, 1964.

B. Materials and Construction

1. Low-cost floor deck and slab studies. In an experimental structure at Beltsville, Maryland, 1 year and 9 months since the installation of wood product underlayments for asphalt tile floors placed above a vapor barrier protected earth fill, no appreciable change has been noted in the moisture of the materials or the subgrade. Warpage of materials at time of installation of the floor is a greater problem than the movement of the floor thereafter.

Asphalt impregnated insulation board serves well as an underlayment, but it is difficult to satisfactorily join this to the hardboard topping to give a good sub-base for asphalt tile. The floors are reasonably stable and are comfortable to walk on. Spaced boards are not a suitable underlayment for hardboard and asphalt tile. Costs of these floors are about 1/2 of that required for a concrete slab-on-grade.

2. Prototype low-cost house construction. An 800 square foot, 3-bedroom low-cost dwelling was constructed for a materials cost of $2,200 near Charles Town, West Virginia. To achieve this low cost, a pole-type framing system was devised to more effectively use the strength of the timber in the framing, a low-cost central heating system was designed and installed, and the least costly materials to give satisfactory performance were selected. The house is also well adapted to self-help construction that requires a minimum amount of skilled trade labor.

3. Foundations for expansive clay soils. Weekly readings of the elevations of four replications each of interior and exterior piers for each of four pier foundation treatments were made from early spring of 1964 until January 1, 1965, when the project was discontinued due to non-availability of funds. In this period of time, no significant difference of movement occurred between pier treatments.

C. Systems for environmental control

1. Attic fan cooling arrangement. The study at Athens, Georgia, to determine the optimum arrangement of an attic fan in relation to the placement of roof or ceiling insulation is progressing. A 36-inch diameter attic fan, with duct, dampers, and control system was installed in a farmhouse near Athens. Large louvers were built into the gable ends to allow adequate air movement. The system is automatically controlled to permit attic ventilation when the outside air temperature is lower than the inside air temperature. The system shuts off, if windows are not open, when rain occurs which might be drawn in through windows or if a fire should start and raise the temperature beyond a set level. Data were obtained with and without fan operation and with the roof and gable ends insulated. Fan operation resulted in a general temperature reduction of as much as several degrees, compared with the fan not operating. A complete analysis cannot be made until other steps in the program have been completed. The tests will be continued during the summer of 1965; during part of the summer, the insulation will be removed from the roof and placed in the ceiling.

2. Warm air heating plenum. Studies were continued during the past winter in expansible House D at Beltsville, Maryland, with additional thermocouples used in the new bedroom. Data were comparable with that obtained last year and indicated more uniform temperatures and less stratification in air temperatures than for the rooms in the basic unit, which were heated through a perimeter duct system in the concrete floor. Thus it appears that the underfloor warm air plenum with narrow slot discharge around the periphery of outside walls is a very satisfactory method of heating.

A warm air plenum system was installed in a low-cost house of pole and panel construction at Charles Town, West Virginia. Tests indicated that the plenum gave excellent temperature distribution with properly sized inlets into the rooms. The slot size was not critical, but significantly wider openings resulted in warmer rooms. This might be a desirable feature in maintaining lower temperatures in bedrooms than in the living areas. Usually the temperature range from floor to ceiling was not over two degrees. A down draft furnace is somewhat expensive in relation to the total cost of a house of this type and might not meet all fire codes. An oil-burning radiant heater installed in the living room, circulating air throughout the house and crawl space by means of the furnace blower, provided a quick warm-up spot for occupants coming in from outside and a temperature range throughout the house of 5 to 8 degrees. Further tests and additional installations are needed to perfect the system.

D. Farmhouse design development

Nine farmhouse plans were released between April 1, 1964, and March 31, 1965, seven three-bedroom and two two-bedroom, all requested by the Southern Region Plan Exchange. Two of the three-bedroom designs have basements. All are 1400 square feet of heated area or less. The two-bedroom plans range from 864 to 1010 square feet of heated area; the three-bedroom from 890 to 1400 square feet. All meet the area limitations of the Farmers Home Administration and also provide a range of lower cost designs to fill the needs of both the Cooperative Farm Building Plan Exchange and the Farmers Home Administration for smaller up-to-date house designs.

The art work and text of Miscellaneous Publications for four plans have been completed, and six additional are in various stages of preparation as of the reporting date.

Floor plan designs for farm labor housing meeting requirements of Farmers Home Administration have been developed and incorporated into a bulletin, "Housing for Seasonal Farm Workers -- Designs and Design Suggestions." Suggested arrangements are shown as guides for architects and builders to design and construct efficient family and dormitory-style quarters in a range of sixes and types.

Floor plan designs stressing features of value to elderly persons have been developed and incorporated in a bulletin, "Multi-Unit Retirement Housing for Rural Areas."

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Design Criteria for Comfort, Health, and Safety

Tayloe, Genevieve K., Parker, W. Russell, and Howard, Mildred S. 1964. Laundry Areas. Miscellaneous Publication No. 961. August.

Howard, Mildred S. and Parker, W. Russell. 1964. Planning Bathrooms for Today's Homes. Home and Garden Bulletin No. 99. November.

Materials and Construction

Simons, Joseph W. 1964. A Comparison of Wear Resistance and Other Physical Characteristics of Counter Surface Materials and Finishes. Georgia Agricultural Experiment Station's Bulletin N.S. 125. December. 24 pp.

Farmhouse Design Development

Agricultural Engineering Research Division. 1964. Four-Bedroom Farmhouse with basement. (Exchange Plan No. 7151). Miscellaneous Publication No. 973. August.

Agricultural Engineering Research Division. 1964. Four-Bedroom Farmhouse - Frame Construction. (Exchange Plan No. 7162). Miscellaneous Publication No. 978. August.

Agricultural Engineering Research Division. 1964. Three-Bedroom Farmhouse with basement. (Exchange Plan No. 7163). Miscellaneous Publication No. 974. October.

AREA NO. 9. LIVESTOCK ENGINEERING (EXCEPT ELECTRICAL)

Problem. The American farmer has about $14 billion invested in service buildings and related structural equipment, over half of it for livestock facilities. Maintenance and new construction amount to another $1.2 billion annually, again mostly for livestock facilities.

Economic conditions are forcing changes in the pattern of livestock production. Producers are trending toward fewer, larger and more specialized enterprises and toward "confinement" types of facilities in their effort to reduce production costs and improve product quality. These trends are demanding more basic knowledge about the effects of environment on the health, growth, production and fertility of livestock; about structures and related equipment for maintaining desirable environments; and about methods, structures and equipment for more efficient handling and feeding. The continuing threat of nuclear warfare demands consideration of types of buildings that will provide protection from fallout for livestock and their feeds, and provide facilities for operation during periods of emergency.

Much more needs to be learned in the laboratory on the relationships between livestock environment and disease transmission, feed conversion rates, and growth and production in order to determine optimum environments. Structures and equipment for economically providing these optimum environments under practical conditions need to be developed and field tested. Closely associated with the environment are flies and other insects, as well as parasites and diseases, that sap the vitality of animals and reduce their productivity. Pesticide residues in animal products are causing much concern. Information is needed on means for keeping these residues from adversely effecting the animals or their products.

Labor is an important element in production costs, and if only family labor is available, the labor requirement limits the size of enterprise. How to adapt existing buildings and other facilities for more efficient production, as herds and flocks are increased in size, or as farms are consolidated, is a major problem area. Cost of replacement or major improvement of existing buildings that are not suited to modern production methods are serious obstacles. Principles, examples and techniques for planning more efficient operations are needed both by farmers doing their own engineering and by those on whom farmers depend for advice.

Many types of structural and handling equipment such as feed bunks, self-feeding silos, and feeding floors, are important to livestock production enterprises. Adaptations and improvements to keep design of such equipment abreast of current production practices and buildings are essential to producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing program involving engineers and architects conducting basic laboratory investigations, application of laboratory results to a production basis, and development of typical plans for livestock structures. The work is in cooperation with the Animal Husbandry, Animal Disease and Parasite, and Entomology Research Divisions of ARS, USDA, and is a contributing project to Cooperative Regional Research Project NE-8, "Essentials of Poultry Housing for the Northeast". Plan development work is cooperative with all the State Colleges through Regional Committees, and with FES, as part of the Cooperative Farm Building Plan Exchange.

A. Dairy Cattle Engineering. Dairy cattle environmental and bio-engineering studies are conducted in a climatic laboratory at Columbia, Missouri, in cooperation with the Dairy Husbandry and Agricultural Engineering Departments of the Missouri Station. AH, ARS, serves in an advisory capacity. The influences of building arrangement, equipment, and chore routines on the amount and drudgery of dairy chores and means of improving these factors are studied in cooperation with the California Agricultural Experiment Station. Typical plans for dairy structures are developed at Beltsville, Maryland.

B. Beef Cattle Engineering. Beef cattle structures and equipment research for hot, dry climates is conducted in cooperation with the California Agricultural Experiment Station at the Imperial Valley Field Station, El Centro. Typical plans for beef structures are developed at Beltsville, Maryland.

C. Swine Engineering. Swine structures and equipment research for hot, dry climates is in cooperation with the California Agricultural Experiment Station at Davis and for hot, humid regions at Tifton, Georgia; in cooperation with the Georgia Coastal Plain Experiment Station and AH, ARS, on an "occasional visit" basis. Typical plans for swine structures are developed at Beltsville, Maryland.

D. Poultry Engineering. Poultry house environmental design criteria are investigated in controlled-temperature laboratory studies at Beltsville, Maryland, in cooperation with AH, ARS, and the basic laboratory data are applied to experimental poultry houses of the NE-8 Regional Project for evaluation.

Field studies on relation of housing structures to poultry disease are conducted in Mississippi in cooperation with the State Agricultural Experiment Station and AH, ARS. Environmental influences on health and housing requirements are investigated in new laboratories at Athens, Georgia, and State College, Mississippi, in cooperation with AH and ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minnesota, a study of the role of environment in the prevention and control of chronic respiratory disease in turkeys is underway in cooperation with the

Minnesota Agricultural Experiment Station. Typical plans for poultry structures are developed at Beltsville, Maryland.

E. Livestock Shades and Shelters. Shades for sheltering livestock are being studied at Davis, California and Tifton, Georgia, in cooperation with the respective State Agricultural Experiment Stations.

F. Sky Radiosity Studies. Studies of sky radiosity (total radiation) are conducted at Davis and elsewhere in California, and at Columbia, Missouri, in cooperation with the respective Agricultural Experiment Stations.

G. Reducing Pesticide Residues in Animal Products. Reduction of pesticide residues in animal products, with beef cattle receiving major attention, is studied at Kerrville, Texas, in cooperation with ENT and ADP, ARS, and the Texas Agricultural Experiment Station.

Federal research effort in this area totals 9.8 professional man-years. Of this number 2.3 is devoted to dairy; 0.8 to beef; 1.2 to swine; 3.4 to poultry; 0.0 to livestock shades and shelters; 0.4 to sky radiosity studies; 1.0 to reducing pesticide residues in animal products; and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

There is an extensive program of both basic and applied research underway at the State Agricultural Experiment Stations in an effort to provide the answers to the continuing series of questions being raised by livestock producers. Demands are being made for more information on the effects of environment on the physical well-being of all classes of livestock, and the way such optimum environments can be economically achieved; on new approaches to meet the growing labor shortage; on methods to adapt existing structures and equipment for greater economy of production; and on structures and related equipment for improved efficiency of feeding and materials handling operations.

Studies are being made on the effect of environment on the health, growth, production and fertility of dairy cattle, beef cattle, poultry and swine. Equipment and systems for efficiently transporting feedstuff into and out of storages and automatically mixing and feeding complete rations are being developed.

Exploring methods for improved care and housing of farm animals with greater economy and labor efficiency are also in progress as well as investigation of ways to modify existing structures and equipment to meet present-day economic conditions.

Much of the work is cooperative with the Department.

A total of 33.5 man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Dairy cattle engineering

1. Increasing efficiency of operations. At Davis, California, studies to determine the effectiveness of herringbone milking parlors in reducing the labor requirement in large-scale dairy enterprises were continued in cooperation with the State Agricultural Experiment Station. Time and travel studies have been made on milking operations in a total of 54 herringbone layouts. Results to date indicate: (1) herringbone milking parlors are just as satisfactory for milking large herds (1000 cows or more) as for small; (2) herds can be milked faster (on a man-minutes per cow basis) in a herringbone parlor, with the same effort, than in any other type of milking layout -- assuming proper arrangement, good routine, and good equipment in proper adjustment; (3) herringbone layouts cost no more, and in some cases less, (on a per milking stall basis) than other types of elevated stall layouts; (4) herringbone layouts have little or no advantage over other types of elevated stall layouts for herds of less than about 35 cows; and (5) some operators place the milking machine on the cow between her hind legs, instead of from either the right or left flank, and believe this suspends the machine from the udder at a more natural angle.

Preparation of a manuscript of facility layouts covering several years' study has proceeded to the final stage. Some of the principles covered have already been used as the basis for technical papers and other publications.

Farmstead planning, covering overall farmsteads, is discussed in Area 10 E.

2. Bio-engineering studies. Basic fundamental studies on the relationships between environment and various dairy animal health and production factors were continued in the psychroenergetic laboratory, and related facilities, at Columbia, Missouri, in cooperation with the Missouri Station.

Data from studies on the acclimation ability of lactating dairy cows conducted in the two preceding years were further analyzed. Exposure of the 10 lactating Holstein cows to the 85°F test condition for nine weeks caused significant decreases (from the 65° levels preceding and following the 85° exposure) for responses associated with heat production. Feed consumption decreased by 10 to 25 per cent and milk production decreased by about 15 per cent. At the same time, responses associated with heat dissipation increased. Only the rectal temperature and pulse rate showed statistically significant trends toward normal levels during exposure to heat.

Studies were continued on the effects of cooling inspired air for lactating Holstein dairy cows. Marked responses to the two levels of cooled inspired-air (60°F and 50°F) were obtained from treatment cows during both test seasons. Responses included increased feed intake and milk production, with

accompanying decreases in rectal temperature and respiration rate. Although the values of each parameter approached "normal", they failed to reach it, indicating only a suitable total environment would provide maximum production and heat relief. Calculated cooling capacity required, based on cooling 28 cfm/cow of 85°F ambient air to 60°F, was 0.23 ton/cow. Actual cooling used in the experimental system for the same conditions, which included heat gains through the head enclosures and air distribution system, was about 1/3 ton/cow. For total barn air conditioning using the same conditions, a calculated capacity of about 2/3 ton/cow would be required.

Maintenance energy of non-lactating cows was studied using resting energy metabolism data of ad libitum and control fed (by rumenfistula) Holstein cows at various environmental temperatures. Initial results indicate the energy required for maintenance was minimal at 95°F; however, the minimal requirement at a normal body temperature was between 65 and 85°F environmental temperature.

A study comparing an air-conditioned dairy barn (maintained at approximately 75°F) with dry lot conditions for housing lactating dairy cows was conducted during the summer of 1964. Production, feed consumption, and rectal temperature of two groups of 16 cows were compared. A switch-back design was used involving three week treatments and three reversals of conditions. Results for this first test season showed highly significant (1% level) differences in rectal temperature and milk production, with the air-conditioned barn providing the more favorable environment in both cases. Data obtained on feed consumption were not suitable for statistical treatment; however, the hay consumption in the barn was consistently less than that in the dry lot.

Field work on farm methods for cooling dairy cattle at Tifton, Georgia, has been discontinued. At the present time, the five years data involving shade and no shade during the summer, shelter and no shelter during the winter, and shade and shade in combination with fans and water sprays are being prepared for publication.

3. Plan development. At Beltsville, Maryland, in cooperation with the Northeastern Regional Plan Exchange sub-committee on dairy housing, sketches for Plan No. 3524, loose housing barn for young stock were developed. Further development will be needed before release to the Cooperative Farm Building Plan Exchange. In cooperation with the Southern Regional Plan Exchange Committee, a calf barn, Plan No. 5970, that was originally developed at North Carolina was released. This design features individual open-front pens for the calves and an enclosed feed room. It is expansible in modules of 12 feet (3 pens). Pole-type construction is specified.

All these plans but the first are included in the Cooperative Farm Building Plan Exchange.

B. Beef cattle engineering

1. Hot, arid climates. These investigations are conducted at Davis, California, and at the Imperial Valley Field Station (El Centro) of the University of California, in cooperation with the Departments of Animal Husbandry and Agricultural Engineering of the California Agriculture Experiment Station.

Studies on sloping floors for beef cattle, as an aid in manure removal and pen cleaning were continued at El Centro. A fourth concrete floor (12 x 14 ft) was constructed and stalls were added to each pen so that 4 animals per pen had the following treatment.

Flat floor - no stalls
Flat floor - with 4 stalls
Sloped floor - no stalls (slope 1 in/ft)
Sloped floor - with 4 stalls (slope 1 in/ft)

The animals were on test from June 17, 1964, to December 2. Activity checks were made and manure was weighed. The results have not been analyzed completely, but it appears the stalls did not accomplish much and the sloped floor does have possibilities for manure removal. This work will be continued in conjunction with slatted floors.

A 112-day study of the effect of shades on beef cattle performance was started in June, 1964, at Davis. Thirty-two steers were divided into four groups, two on concrete and two on dirt. One pen of each of these had access to a 12'x24' shade (10 ft high). The following are the feed trial results.

	Concrete		Dirt	
	Shade	No Shade	Shade	No Shade
Av. daily gain	3.18	3.26	3.09	3.06
Lb feed/lb gain	7.83	7.70	7.69	7.35
Av. initial wt., lb	669	671	655	608
Total gain, lb	356	365	346	343

The average maximum and minimum temperatures during the period were 88.3°F and 53.0°F. There were no significant differences in the results indicating that shades are apparently not needed in an area like Davis for beef cattle. This will be repeated on an expanded scale.

Plans for a 35'x65' prefabricated metal laboratory building for beef cattle housing studies at El Centro have been drawn and construction is expected to be completed some time during the fall of 1965. The building will contain a main laboratory room that will hold twelve animals, individually penned, and three working rooms - all provided with equipment for controlled cooling.

2. Hot, humid climate. Inactive during reporting period.

3. Plan development. At Beltsville, Maryland, in cooperation with the Western Regional Plan Exchange Committee, Plans 5962 and 5969 were developed for tilting tables for handling calves. The first is a heavy duty wooden, permanent structure to handle calves up to 600 pounds; the second is a portable pipe-framed table designed for calves not exceeding 450 pounds.

Plan No. 5974, for a beef cattle corral, shows arrangement and dimensions of pens and facilities, but does not give details of construction.

These plans are all included in the Cooperative Farm Building Plan Exchange.

C. Swine engineering

Swine environmental studies were continued at Davis, California, in cooperation with the Animal Husbandry and Agricultural Engineering Departments of the California Agricultural Experiment Station. These include humidity effects and moisture loss measurements in a controlled laboratory, and production field tests on sprinklers, swine exercise, and ultra-violet lights for swine. Tests were continued at Tifton, Georgia, in cooperation with the Georgia Experiment Station, on sprinkling and shades for swine. There is no longer a USDA Agricultural Engineer at the Tifton station, but cooperation is maintained by periodic visits of the Davis personnel to Tifton.

1. Effect of humidity on swine. Humidity-growth studies were continued in the controlled laboratory at Davis. The third test in the series (identical to the second) was completed, using pigs initially weighing about 61 lbs each. Three pigs were placed in each of the three chambers inside the large test chamber. The relative humidity of each house was held constant at 45, 70, or 90% RH, while the dry bulb temperature of each house was maintained at the optimum for the weight of the pigs. A summary of growth for tests II and III are shown below.

Average Daily Gain (Lb/day)	45% RH	70% RH	95% RH
Test II	1.56	1.48	1.41
Test III	1.57	1.42	1.56
Lb Feed/Lb Gain			
Test II	3.71	3.67	4.16
Test III	3.49	3.67	3.06

There is apparently no effect of relative humidity, in the ranges studied, when the dry bulb temperature is near optimum. The next test will be with dry bulb temperatures 10 °F above the optimum.

2. Pig sprinklers for hot, arid climates. Studies on sprinklers for pigs in a hot-dry climate, at Davis, to determine nozzle size and operational

regime, were continued in 1964. Five groups of nine pigs each were involved in the 63-day trial that began on July 1. Average maximum temperature was 89.5°F, average minimum was 54°F, and the mean was 70.6°F. The pertinent results are shown below.

Nozzle size (Monarch)	4.6	4.6	6.4	6.4	Control
Time on	On 15 Min Off 15 Min	Continuous	On 15 Min Off 15 Min	Continuous	-
Water use (gal/hr/pen)	3.08	6.16	4.09	8.18	-
Av. daily gain, lb	1.54	1.53	1.46	1.44	1.34
Lb. feed/lb gain	4.85	4.48	4.92	4.58	4.53

There were no significant differences between treatments. In a similar test in 1961, the control group had a highly significant reduction in gain below the sprayed group. The average mean, maximum and minimum temperatures in 1961 were 77.1, 96.8, and 60.1.

3. Sprinkling for hot, humid climates. Studies were continued at Tifton, Georgia, to determine the value of shade and shade-plus-fogging for growing-finishing pigs and for gestating sows and gilts in a hot, humid climate. The same movable shades on skids and lots were used as previously.

In 1964, 40 pigs (avg. 49.1 lbs each) were held in small pasture lots (10 pigs per lot), two lots had shade plus fogging under the shade and two lots had shade only. Again, an analysis of variance indicated a highly significant difference (at the 0.01 level) in rate of gain, but not in feed efficiency, due to the treatment.

In 1964, 16 bred sows and 16 bred gilts were in temporary pasture lots (8 animals per lot), two lots had shade plus fogging under the shade and two lots had shade only. Due to the unusual cool weather during the latter part of the gestation period, no rectal temperature or respiration rates were recorded. Again, the average number of live pigs farrowed, birth weight of live pigs, number of pigs weaned and adjusted 56-day weight of pigs appeared to be equal for the two treatments. This is the third year's data, and it is estimated that approximately four years' data will be required for analysis.

4. Stand-up feeding. A fourth stand-up feeding test was conducted with the following treatments: (1) control pen using ground-level feed troughs; (2) early stand-up, using elevated troughs from start of test; and (3) late stand-up, using elevated troughs only after pigs reached about 130 lbs. The results, which contained no statistical differences, are as follows:

	Control	Early Standup	Late Standup
Av. daily gain, lbs	1.57	1.56	1.60
Loin area, sq. in.	3.90	3.93	4.18
% ham	19.70	19.90	18.10
% loin	15.10	14.50	15.20

A treadmill, designed for 6 pigs, was mounted below one of the stand-up feeders, so that the pigs walk on their hind legs while eating, and was put in operation on February 3, 1965. The pigs are fed twice daily with the treadmill running about 2.5 inches/second for two hours at each feeding. The purpose is to see what controlled exercise might do to relative weight percentage and quality of different parts of the carcass, and the effect on feed efficiency. This test is still in progress.

5. Moisture loss. Studies on swine moisture loss were continued in the laboratory at Davis. A method was developed for measuring separately the moisture lost by swine through the skin and as respiratory loss from lungs and mouth. This is accomplished by using an airtight rigid plastic box to contain the pigs individually. By means of a fitted mask, respired air is exhausted from the box. The moisture content of inlet and exhaust air from the tent is measured. The increase in moisture with the mask off represents total vaporized moisture. With the mask on, only skin moisture is measured.

Some preliminary results are shown below. The effects of dew point (vapor pressure) and dry bulb temperature on moisture loss of 220 lb pigs are as follows:

Temperature, °F	Moisture loss, grams/min at 53°F dew point		
	Total	Skin	Lungs
84	1.27	0.61	0.66
68	0.96	0.50	0.46

Dew Point	Moisture loss, grams/min at 84°F dry bulb		
	Total	Skin	Lungs
71	2.10	1.35	0.75
53	1.27	0.61	0.66

6. Ultra-violet light. At Davis, California, 6 pens of pigs, 5 pigs per pen, were exposed to ultra-violet light at 2537 angstroms, 24 hours per day, from December 14, 1964 to February 23, 1965. Data are not yet analyzed, but there were no apparent significant effects of the light on health, gain, or feed efficiency.

7. Plan development. Plan No. 5947, Portable Shade for Hogs, was developed for the Cooperative Farm Building Plan Exchange. It is based on the results of research done at Tifton, Georgia.

D. Poultry engineering

1. Calorimeter studies. Investigations to determine heat and moisture production of broilers in the respiration calorimeters at Beltsville, Maryland were continued.

Studies with Athens Randombred (ARB) broilers were completed. Test temperature levels ranged from 5 to 30°C to 5°C increments. An additional study at 5 and 20°C was conducted with a commercial broiler (CB) strain to assess the engineering data obtained from ARB studies. All studies took day-old chicks through 9-weeks of age.

All brooding was started with calorimeter air temperatures ranging from 85 to 94°F and humidity near 60%. The temperature was dropped from brooding to test levels at various rates to find a suitable temperature reducing regime for the commercial broilers.

The preliminary heat production data per unit live-weight were similar for both strains. The CB birds, however, consistently grew at a faster rate. By the end of 9 weeks, the CB group averaged 1/3 heavier than the ARB's. Hence, both heat and moisture emitted per bird will be more for the CB than for the ARB.

Both strains emitted maximum heat per unit live-weight at 10 to 15 days of age. In previous tests with the New Hampshire x Cornish birds, the heat peaked near 25 days of age. This is an inference that modern broilers may be able to control body temperature much earlier than those of 15 to 20 years ago, indicating an opportunity for revising brooding temperature and reducing brooding cost.

The ARB birds demonstrated almost identical growth rate at any given test temperature level. These broilers had good growth rate between 50°F (10°C) and 77°F (25°C).

At 86°F and below 60% relative humidity, chicks 1 to 3 days old huddled excessively. Humidity of 75 to 80% at 86°F was apparently too comfortable as it appeared to decrease feeding activity.

The fresh fecal moisture content of both strains was within 80 to 83% on a wet basis. The higher value persisted at air temperatures above 60°F.

2. Southeast Poultry Research Laboratory. Engineering activity at this recently completed facility is largely still concerned with development, procurement, and installation of test equipment and instrumentation for the engineering portions of contemplated multi-discipline research programs.

During the report year, two prototype environmental cabinets, with control panels, were completed and partially performance-tested. A third control panel was almost completed. A third cabinet (of somewhat different design from the two previously constructed) is approaching completion. Shakedown and performance tests were made on the two completed cabinets. Test report is not yet available.

Each cabinet has separate temperature program control for cabinet top, bottom, and each sidewall, and for air temperature and air dewpoint within

the cabinet. Controller response is rapid. Panel temperature change from maximum to minimum can be obtained in a couple of minutes or less. Humidity control has not been as good as hoped for, but this is expected to improve with further modification of the control system.

Four insulated rooms in environmental building number 8 were completed and are ready for installation of environmental control equipment upon delivery.

3. Field observations on relation of housing to disease in broilers in the South Central States. Work in Mississippi, in cooperation with AH and the Mississippi Station, has continued.

Insulation of the ceiling and the end walls of broiler houses in this area results in a reduction in fuel used for brooding, a very slight decrease of feed required to give a pound of gain in the winter time, and less likelihood of death from heat prostration in the summer time when compared to houses having no insulation. Techniques for proper management of insulated houses need to be refined and taught to caretakers to obtain maximum benefits from insulation.

Except for the greater mortality experienced in extremely hot weather for a house with the ridge oriented in a N-S direction, no significant differences have been found in the production (weight, feed conversion, and condemnations) between houses with a ridge oriented N-S and those with a ridge E-W.

Studies comparing the performance of the new gas infrared brooder with the old standard canopy brooder indicated little difference in production results, although the infrared brooders consumed more fuel.

Studies to determine the adaptability of materials for broiler house curtain walls and their effects on environmental conditions inside the house have shown little advantage in production results for any of the materials studied.

Height of sidewall studies showed little production difference between broiler houses having wall heights of 6 1/2, 7, and 7 1/2 feet.

4. South Central Poultry Research Laboratory. Engineering research to determine by experimental procedures the effects of construction, equipment and management of poultry housing structures on broiler diseases and condemnations is being initiated at this newly constructed facility in cooperation with AH and the Mississippi Station.

Initial work will be conducted in four research poultry houses, each having four pens, on the laboratory farm and will be concerned principally with the influences of insulation and brooding equipment on selected environmental factors associated with the economics of poultry production.

5. Influence of turkey housing environment on disease. Work at St. Paul, Minnesota, in cooperation with the Minnesota Station, has continued. Turkey eggs have been dipped in chemicals in attempt to eliminate mycoplasma (PPLO) infections. The poults from these eggs have been grown in two types of housing and under varying environmental conditions. Although the egg dipping has not resulted in the complete elimination of all mycoplasma infections, it has resulted in a reduction of the airsacculitis caused by these micro-organisms. Further attempts to completely eliminate these micro-organisms will be made by combining the egg dipping with a medication program during the growing period.

During the winter months it was necessary to furnish supplemental heat to all test flocks. Attempts to lower pen temperatures below 50°F resulted in piling. This, along with the necessity of ventilating adequately to keep the ammonia at safe levels (below 20 ppm), appears to rule out minimum type housing for turkey broiler flocks.

The substitution of very small amounts of litter, added frequently, for thick layers of litter materials seems to have some advantages. The droppings do not become buried in the litter where the ventilating air cannot dry them.

Air sampling has revealed a very large population of micro-organisms per cubic foot of air. The bacteria counts reveal a uniformly high count (40,000 per ft^3) throughout the growing period (8 - 14 weeks). Attempts to control these through the use of aerosol disinfectants will be made.

6. Plan development. The Arkansas Extension Service, the Cooperative Farm Building Plan Exchange at Beltsville, and the poultry sub-committee of the Southern Regional Plan Exchange, cooperatively developed a pole-type broiler house, 40 feet wide with length variable in modules of 16 feet. It features insulated hinged wall panels which may be opened for ventilation. The Plan Number is 5972, Broiler House, 3 sheets.

E. Livestock shades and shelters. Reported under 9-B-1 and 9-C-3.

F. Sky radiosity studies

Sky radiosity studies were continued at Davis, California (dry climate, clear sky) and at Columbia, Missouri (humid climate, overcast sky), in cooperation with the respective Experiment Stations. The quantity, quality, and variation of various parts of the sky are being studied in respect to the effect they may have on design and orientation of farm buildings and structures.

At Davis, California, two directional thermopile-type radiometers were used to measure the down coming diffuse sky radiation (wavelengths less than 3.5 microns) and atmospheric radiation (wavelengths greater than 3.5 microns) from various areas of the sky hemishere. One radiometer responded

only to diffuse sky radiation through a quartz filter, while the other one, covered with 2-mil polyethylene film for wind protection, provided a measure of total radiation. Atmospheric radiation was obtained as the difference between the two observations. Equations were developed for using the two-radiometer system to measure sky radiance. A field method of determining the absorptance of the polyethylene shield was developed.

Measurements were made at sea level (El Centro), 51 ft (Davis), 4,147 ft (Bishop), 9,200 ft (White Mountain), and 10,500 ft (White Mountain) during August and December of 1964. Some additional measurements were made in October of 1964. A set of measurements at any location was made once each hour from 9 AM to 3 PM inclusive. Total and diffuse sky radiation were measured at the zenith and at 45° starting from true north on azimuth circles of 15, 30, 45, 60, and 75 degrees above the horizon. Additional observations included irradiation on a horizontal surface and at normal incidence to the sun.

The spatial distributions of both downcoming diffuse sky and atmospheric radiation were found to be non-isotropic. The maximum flux density of diffuse sky radiation was often more than three times greater than the minimum that was observed from sky areas between sun azimuths of 120 and 240 degrees, and at elevation angles of 80 to 100 degrees from the sun's beam. Maximum amounts of both diffuse sky and atmospheric radiation were observed near the sun. The maximum flux density of atmospheric radiation was from 30 to 40 per cent greater than the minimum that was observed from sky areas between sun azimuths of 90 and 270 degrees, and near the zenith.

A reduction was noted in the amounts of both diffuse sky and atmospheric radiation as the site elevation above sea level increased. The diffuse sky radiation decreased at a faster rate, and the atmospheric radiation decreased at a slower rate, from sea level to 4,000 ft than from 4,000 to 10,500 ft.

Atmospheric radiation ranged from 73 to 91 per cent of total radiation; the averages for all data were 83 per cent atmospheric radiation and 17 per cent diffuse sky radiation.

Sky maps have been developed that show lines of equal flux density over the sky hemisphere as an aid in visualizing the spatial distribution of downcoming diffuse sky and atmospheric radiation. These indicate the magnitudes of the anisotropic distributions.

At Columbia, Missouri, after necessary calibration of the radiometer and recording potentiometers for this project, a series of four measurements were made. These included clear, cloudy, and partly cloudy days. Although the data have not yet been analyzed, preliminary examination has revealed some difficulties in the technique of measuring short-wave radiant fluxes from the sky. After further analysis, modifications in the method of obtaining short-wave radiation measurements may be developed.

G. Reducing pesticide residues in animal products

Development and testing of self-treating sprayers for control of biting flies on cattle was continued in cooperation with ENT at Kerrville, Texas. Field studies with 3 different automatic sprayers were conducted. Automatic sprayers pressurized with small electric air-compressors were simpler, more rugged, and more reliable than those with liquid pumps tested in 1963. Self-contained automatic sprayers, using pre-compressed oxygen or nitrogen for pressure and storage batteries for automation, controlled horn flies on range cattle but did not utilize the pre-compressed gases efficiently. Automatically controlled foggers that applied only 2 to 4 ml of material to each animal were subjected to preliminary testing and were partially successful.

A 1-ml "spot-treatment" for the control of horn flies on cattle was tested in the laboratory. The small volume of spray was applied daily to an area of about 1 square-foot on the withers of experimental animals, with concentrations of ronnel and malathion ranging from 1 to 10%. The spot-treatments were practically as effective as 50 ml sprays, applied daily, when similar amounts of active ingredient were used. The spot-treatments have the advantage of requiring simpler and cheaper sprayers than other methods, and automated systems may be constructed more easily. By applying the insecticide to areas on the foreparts of dairy cattle, it may be possible to reduce the chances of direct contamination of milk. Field tests and residue tests are planned for next year.

A series of 6 spray distribution tests were conducted. Spray distributions were determined by collecting hair samples from selected locations on the bodies of treated cattle, and analyzing the samples for insecticide content, using a simplified procedure for detecting coumaphos (Co-Ral). The tests indicated that 8-nozzle automatic sprayer booms would provide spray distributions as uniform as those provided by power-sprayer applications of 1 gallon. Nozzle arrangement and wind appeared to be the most important factors affecting the automatic sprayers. The weight of hair coats on animals treated by power sprayers had significant effects on the amounts of retained insecticide. Cattle sprayed in winter may retain 3 to 4 times as much insecticide on the hair coats as those sprayed in the summer.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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AREA NO. 10. CONSTRUCTION STANDARDS, WATER SUPPLY, WASTES DISPOSAL, AND FARMSTEAD PLANNING

Problem. Farm buildings inventoried at $28 billion in the United States are the production, storage (and sometimes the processing) centers of food and fiber for the nation. Annual cost of repair, remodeling and new construction of the farm plant amounts to $2 billion, an expenditure that may wastefully use materials through lack of sufficient knowledge of the loadings to which buildings are subjected--the pressures of soil movement, wind gusts, snowfalls, and stored product loads.

Construction may be wasteful because we lack knowledge of design methods for inherently strong shapes such as hyperbolic paraboloids. Our knowledge of materials and materials fastening is incomplete and often inaccurately used in special applications encountered in livestock production.

Product application research stimulates the economy of manufacturers of building products (lumber, steel, cement, plastics, asphalts, aluminum, inorganics), building fabricators, farm producers and the general consumer. Research is needed on loads imposed on buildings by nature; properties of materials for strength, weathering, aesthetics and durability; and the proper combination of materials of construction for the most economical and effective structures.

In many localities urban building codes that may be unduly restrictive are being extended to cover farms, where the hazards of public occupancy and damage to the property of others are not present to the degree that they are in urban areas. Those who draft building and fire codes need design information that would be realistic for farms.

Recent action programs involving recreational facilities in rural areas need to be supported with plans for sound, workable structures and other facilities such as cabins, boat landings, shelters, etc. There is also need for plans for roadside stands and similar farm marketing structures in support of rural area development programs.

An adequate supply of satisfactory water is essential to the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead--both in quantity and quality. The "old well" and under-sized distribution system are less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truck load at considerable cost; others are developing farm ponds as sources of farmstead water; some continue to operate with a supply that is becoming less and less adequate.

Surface waters normally require disinfection to guard against water-borne diseases such as typhoid, dysentery, other gastro-intestinal disorders, and infectious hepatitis. Often they also require filtration and other treatment to remove undesirable foreign material. Deeper ground waters are often highly mineralized (hardness, iron, sulphur, and others), and expensive or impossible to treat adequately. Pesticide chemicals occasionally show up in farmstead water systems. Data on water demands and water systems requirements of the modern farmstead are needed to guide farmers in planning water systems and selecting equipment, to enable extension workers to adequately advise farmers, and to guide equipment and appliance manufacturers and sanitary code-making bodies. Simpler, more reliable, and less costly methods and equipment are needed for treating farmstead water supplies to improve their quality.

Disposal of organic wastes--principally sewage and manures--is becoming more and more of a problem on the modern farmstead. The cattle, hogs, horses, sheep, and poultry on farms in the United States produce more than 2 billion tons of manure annually. The problem is particularly acute with respect to confinement-type livestock operations on the fringes of metropolitan areas--where the total amount of manure is concentrated in the confinement area. Under these conditions, it is difficult to avoid creating a sanitation hazard or a public nuisance. Economical, sanitary means of disposition need to be developed. Among means that need to be investigated are lagoons, irrigation systems, subsurface absorption systems and reclamation. Development of improved methods for disposing of sewage in those rural areas where conditions are adverse to the conventional septic tank system (high ground water, shallow rock, non-absorptive soils, restricted areas) is needed.

The arrangement plan of the farmstead has an important bearing on its efficiency, appearance, and livability. For example, convenient locations for feed and bedding storage ease the distribution chores. A 40-cow dairy herd will use approximately 240 tons of silage, 60 tons of grain, 40 tons of hay, and 20 tons of bedding annually. Research is needed to evaluate the various planning factors in the light of current equipment and practices and to develop planning principles and guidance materials for the benefit of farmers--particularly those contemplating changes.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in basic and applied research on structural aspects of farm buildings, farmstead water supply, farmstead wastes disposal and farmstead planning. The program is cooperative with selected State Agricultural Experiment Stations and other appropriate agencies.

A. Meteorological factors affecting the design of farm structures, such as climate and weather (wind, storms, frost, etc.), are studies at Beltsville, Maryland, and selected field locations.

B. Construction Standards, such as serviceability and safety, for design of farm buildings are studied at Beltsville, Maryland, and selected field locations. Liaison is maintained with the American Society of Agricultural Engineers, American Standards Association, National Safety Council, National Fire Prevention Association, and other organizations concerned with standards and safety in farm structures.

C. Materials and Construction Methods for farm buildings are studied at Beltsville, Maryland; at Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station; and at State College, Mississippi, in cooperation with the Animal Husbandry Research Division and the Mississippi Agricultural Experiment Station.

D. Water Supply and Wastes Disposal for the farmstead are studied at College Park, Maryland, in cooperation with the Maryland Agricultural Experiment Station. Liaison is maintained with the Public Health Service, the Water Systems Council, the American Society of Agricultural Engineers, and other organizations concerned with rural sanitation.

E. Farmstead Planning studies are made at Beltsville, Maryland, at St. Paul, Minnesota, in cooperation with the Minnesota Agricultural Experiment Station, and at Davis, California, in cooperation with the California Agricultural Experiment Station.

F. Fallout Protection work for the farmstead is conducted at Beltsville, Maryland, and selected field locations. Liaison is maintained with the Office of Civil Defense, Department of Defense, and other appropriate agencies.

The Federal effort in this research area totals 7.3 professional man-years. Of this number 0.6 is devoted to meteorological factors; 0.5 to standards for serviceability, safety, etc.; 2.2 to materials and construction methods; 2.4 to water supply and wastes disposal; 1.0 to farmstead planning; 0.0 to fallout protection; and 0.6 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is confined largely to basic and applied studies of structural components for farm buildings; techniques and systems for adequate and safe water supply; and improved methods for economical and sanitary disposal of organic wastes on the modern farmstead.

Representative of the investigations currently in progress in the farm buildings field are those which are concerned with analysis, design and testing of rigidly connected frames and panels; studies of single cover stressed skin designs for clear span roofs; development of wall and roof designs to resist storm damage; tests of the structural stability of farm buildings under accelerated cycles of loading and adaptations of new construction techniques to problems of farm service buildings and animal shelters.

In the water supply area research is underway to develop ways to economically filter and treat surface waters in order to provide an adequate and sanitary quantity of water for the farmstead operations. Studies are also being made on the problems concerned with demineralizing deeper ground waters.

A widespread research effort is in progress which is attempting to investigate all of the factors involved in the complicated problems concerned with disposal of farm waste materials, particularly concentrated manures resulting from confinement-type livestock operations. The problem is most acute and the public is demanding a fast solution to this unsanitary and potentially dangerous health hazard.

Much of the work in this area is cooperative with the Department.

A total of 27.8 man-years of effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Meteorological factors

At Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station, dynamic wind pressures are being measured on a full scale test structure that can be quickly rotated to present different exposures to the wind. Instrumentation has been perfected to accurately record pressures and pressure changes that occur in one one-hundredth of a second. Data analyzed have been primarily for medium velocity winds, 20 to 45 mph. Instrumentation now available can simultaneously measure the pressures on only 4 points on the building. Sufficient data have not been analyzed to presume any statements regarding the validity of values for wind loading that are currently used for design of buildings.

Frequency of dynamic pressure cycling has many aspects that appear random. Whether or not a pattern of frequency can be detected is as yet unknown. Conditions existing on the actual building in the windstream are different from those models tested in a wind tunnel, but the significance of these differences when applied to building design has not been determined.

B. Construction Standards

At Beltsville, Maryland, in cooperation with the American Society of Agricultural Engineers, The American Standards Association, the National Safety Council, and the National Fire Protection Association, work continues on reviewing, proposing, and acting as consultants to those engaged in preparing standards for the safe erection and use of structures. The American Society of Agricultural Engineers has accepted standards on fallout protection for livestock, and on wind and snow loads used for the design of rural buildings.

Current work with ASAE points toward the compilation of a standard on fire safety in farm building design and construction.

C. Materials and Construction Methods

1. Hyperbolic paraboloid (HP) shapes for farm structures. Laboratory test facilities were installed at Beltsville, Maryland, to evaluate the deformations caused by uniformly loading HP diaphragms built of lap-bolted, wood product materials. Air bags inflated to measured pressures were used to uniformly load an edgeless diaphragm. Buckling and undulations complicated the interpretation of strain gage readings. The test will be repeated with better strain gage locations, then these data will be compared to those obtained from the performance of an identical shell rigidly fastened at the edge.

Tests made up to this time indicate that these shapes offer material savings in the construction of a great variety of farm structures. The shape is adapted to the use of timber, steel, concrete, or, if economically feasible, polymer plastics.

2. Rotational strength of nailed joints. From tests made at Blacksburg, Virginia, reliable joint moduli may be computed and compared to section moduli of timbers that are lapped and nailed. This technique makes a joint as strong as the timber to achieve continuity of roof purlins, floor joists and similar deck supporting construction. Design of timbers as continuous beams results in lighter beams than those specified when simple beams support an equal load.

3. Plan development. Continuation of the publication of results of tests on lapped nailed trusses, made at Beltsville, Maryland, resulted in Cooperative Farm Building Plan Exchange Plan Number 5973, 32 Foot Utility Truss. This lap-nailed construction is designed to support a total load of 6,400 pounds (200 pounds per foot of span). The slope is 4 in 12.

At Beltsville, Maryland, the Cooperative Farm Building Plan Exchange has worked with the Midwest Plan Service, the Southern and the Western Regional Plan Exchange Committees for developing plans for recreational and marketing structures -- to emphasize greater service of the farm to

the urban people. Working drawings were developed for the following items:

Boat landing (Exchange Plan No. 5975) was prepared for the Rural Community Development Service. It provides covered storage for a small motorboat. Provision is made for hoisting the boat clear of the water when it is not in use. This feature adapts the landing to moderately rough water.

Cabin (Exchange Plan No. 5968) is a concrete masonry cabin that can be easily expanded to two or three bedrooms. It has trusses experimentally developed at Beltsville.

Roadside stand, a multi-purpose, permanent stand of pole-type construction. It is planned for ease of erection and may be built in stages. Working drawings have not been released.

Two display stands for produce feature semi-circular stepped shelves that may be cut from a single sheet of plywood. Both may be easily disassembled for moving or storage. Working drawings have not yet been released.

D. Water supply and Wastes Disposal

1. Farmstead water systems. Studies on farmstead water supply system design criteria are continuing in Maryland, in cooperation with the Maryland Station, National Fire Protection Association, Johns Hopkins University, Federal Housing Administration, Washington Suburban Sanitary Commission and selected farmers.

Major effort was devoted to determination of farmstead water requirements. Progress is limited by the capacity of existing available farmstead water systems. Considerable evidence has been accumulated on the labor saving potential of improved water systems. Cooperation with the Sanitary Engineering Department, Johns Hopkins University, which is conducting a residential water use study for the Federal Housing Administration, made it possible to collect an appreciable amount of water use data in 11 homes served by the Washington Suburban Sanitary Commission. These data are not yet fully analysed.

Design criteria developed on the project were applied to improving the water system of a large Maryland dairy farm that was troubled with lack of capacity. The improvements resulted in increasing the capacity of the water system by 500% and reducing the cost per g.p.m. of capacity by 72%. Had it been possible to construct the improved system "from scratch" its cost would have been only slightly higher than that of the original system. In addition to the increased water system capacity, the farm now has a 250 g.p.m. fire hydrant with normally over 15,000 gallons available for fire protection.

Considerable effort was devoted to gathering and developing material for a technical publication on the fire fighting potential of individual farmstead water systems. Much of the technical data required have been found to be either not available or, if available, not valid. Because of the great increases in investment in farmstead facilities in recent years this is of major importance to farmers today -- yet few realize how little cost is involved in maximizing the fire fighting potential of their water systems. For example, tests conducted at the University of Maryland fire tower show that use of 1 1/2" hose is very desirable to increase the fire fighting potential of individual water systems when pump capacity exceeds 20 gpm at 35 psi.

A portable booster pump for hydraulic cleaning and waste removal was tested on several farms, effecting time savings of 1/2 to 1 hour per day. The farms on which the greatest time savings have been reported cannot supply the pump directly and resort to use of an intermediate storage tank, indicating need for increased capacity in the systems.

The feeding floor at the University of Maryland Swine Research Unit, which has been cleaned with this pump for the past two years, has required no insecticides during this time because of the increased cleanliness of the unit. As the study progresses it appears that better results are obtained with lower pressures and higher volumes, using larger nozzles. At present 12-13 gpm at 45-50 psi appears preferable to 10 gpm at 60 psi.

2. Pesticide pollution of farmstead water supplies. Work on a new project to assemble information on the use and handling of pesticides on and around the farmstead and to develop methods for preventing their entry into farmstead water supply systems and for dealing with those that do enter was started in January 1965 at Watkinsville, Georgia, and in February at Beltsville, Maryland. Efforts to the reporting date consisted principally of reviewing literature on the problem, developing a work program and procuring facilities.

3. Farmstead manure disposal. Laboratory and field studies are continuing in Maryland, in cooperation with the Maryland Station. Work this year was concerned almost exclusively with the hydroponic possibilities of lagoon effluent clarification and salvage of plant nutrients in the form of an animal feed crop. A 3-week laboratory test with the grass Panicum Agrostoides showed marked reductions in dissolved solids (82%). Green cut yields were in the range of 70-80 tons/acre inch of effluent. Effluent from two different lagoons was used, one serving a milking parlor and bottling plant and the other a swine farm. Distilled water was added for makeup. It was observed that the grass grew well in the effluent from the dairy lagoon but appeared to be dying in that from the swine lagoon -- leading to a subsequent finding that effluents may need to be

"conditioned" for the purpose. This was borne out in tests with other, more desirable, grasses such as orchard, fescue, rye and timothy.

Ash analysis of fresh green cut tops was in the range 1.7 - 2.3%. Tests on nutrient levels will be performed.

4. Rural community sewage disposal. A PL 480 project to reduce costs involved in treatment and disposal of sewage from small rural communities through determination and application of optimum algal-protozoal and algal-bacterial symbiotic balances was initiated at the M.S. University of Baroda, Baroda, India, during the year. No findings have been reported as of the reporting date.

E. Farmstead planning

1. Farmstead model layout studies. Studies on the use of models for analyzing farmstead layout problems have been continued in cooperation with the Minnesota Experiment Station at St. Paul, Minnesota. These studies show that such models are very useful in making a three-dimensional presentation of possible farmstead layouts. The successful use of models to analyze farmstead design problems in this study would indicate that most operators who are planning either a new setup or an expansion of their present layout might profit by using a scale model as one of the steps in planning their final layout design. The procedure to be followed in using the model method of planning is as follows: first, determine the management system and space requirements necessary in the final plan; the next step is to make and set up the models, moving them to all possible design locations before selecting the layout which best satisfies the specifications set forth in the first step; and lastly, plan the final construction, or, if it is an expansion program, plan a construction program to meet the needs of the increasing herd size.

2. Chore time standards. Studies on time standards for performing farmstead work elements are continuing in cooperation with the Minnesota Station, at St. Paul, Minnesota. A new series of studies was started to determine design and use recommendations for slat floors, free-stalls, and associated feeding equipment for dairy cattle. These studies are applying previously developed work element time standards to management systems using inside resting facilities and outside feeding. Observations are also being made to determine manure handling problems encountered with slat floors under both cold and warm operating conditions, bedding requirements for free-stalls, and feeding equipment layout arrangements for most efficient use of free-stall and/or slat floor systems.

An exploratory trial operation showed that it takes several days to get animals accustomed to using the slat floor, free-stalls, and animal operated doors. Prolonged freezing weather caused difficulties with the slat floor operation and indicated need for additional study to determine if the advantages of handling manure as a liquid during the greater portion

of the year would justify the difficulties encountered during shorter cold weather periods. The animals remained exceptionally clean throughout most of the trial and indicated that properly designed paved walkways should keep them out of the mud.

F. Fallout Protection

No reportable progress during reporting period.

PUBLICATIONS - USDA AND COOPERATIVE PROGRAMS

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Water Supply and Wastes Disposal

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Farmstead Planning

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AREA NO. 11: ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR INSECT CONTROL AND OTHER FARM USES

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since there is zero tolerance of DDT in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled by electrical methods and equipment alone or in combination with insecticides, chemosterilants, and biological attractants?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform maturation with increased practicability of once-over harvest programs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of eleven States. Electrical and physical methods for corn borer control are studied in Iowa, cotton insect control in South Carolina and Texas, with the Texas project contributing to Regional Research Project S-37, Basic Factors Involved in Control of the Pink Bollworm. Electrical and physical methods of tobacco insect control are studied in North Carolina, South Carolina, Kentucky and Virginia, and vegetable insect control and light trap

design in California and Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland. Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska, Tennessee, and Washington.

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination are in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperative help on some phases of studies was furnished by the Crops Research Division, ARS, the Asgrow Seed Company, the Agricultural Engineering Departments of the University of Idaho and Texas A&M University, and others.

Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee in cooperation with the Departments of Agricultural Engineering, Agronomy, and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. At Pullman, Washington, effects of glow-discharge radiation on germination of seeds and early plant growth were studied in cooperation with the Washington Agricultural Experiment Station, Washington State University.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 14.3 professional man-years; of this number 5.9 are devoted to electric traps for insect survey, destruction and control; 1.3 to components and design of electric insect traps for survey and control; 2.0 to physical methods of fly control; 4.4 to radiofrequency treatment of grain and forage seed; and 0.7 to program leadership.

A 4-year contract has been awarded VPI to investigate the possibility of attracting or repelling flies with sound.

PROGRAM OF STATE EXPERIMENT STATIONS

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production.

Investigations in progress, many of which are cooperative with the Department, involved the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics; exploration of the feasibility of using ultrasonics and electric shock to control rats, mice and birds; studies of the possibilities for a major advancement in the technology of small particle depositions through the application of electrostatic, thermal or other inertial forces; and use of light sources of various wavelengths for attracting and collecting insects which infest many of our economic crops.

A total of 2.0 professional man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Electric Traps for Insect Survey, Destruction and Control

1. Electric Traps for Vegetable Insects

Research on control of vegetable insects using electric light traps, on use of traps for insect survey, and on response of economically important insects to electromagnetic radiations was conducted in Indiana. This work was cooperative with the Purdue University Agricultural Experiment Station through the Departments of Agricultrual Engineering and Entomology and was partially supported by the Indiana Electric Association.

Electric traps for determination of the migration and occurrence of corn earworm moths and occurrence of several other insect species of economic importance were studied in cooperation with personnel of the Purdue Department of Entomology as part of Regional Project NC-67, Migration of Aphids and Noctuids.

Field experiments to investigate the effectiveness of electric insect traps for controlling insect damage in tomato production were expanded and continued for the seventh consecutive season at Lafayette, Indiana. Studies were made in experimental garden areas using three types of insect traps. Fan, gravity, and electrocutor-grid traps were equipped with five 15-watt blacklight (BL) fluorescent lamps as attractants. Two traps were placed 750 feet apart in each of three 900-foot-long strips of tomato plantings with each strip 250 feet apart. Effectiveness of the traps in protecting tomatoes from tomato and tobacco hornworms, corn earworms (tomato fruitworms), cutworms, and drosophila was evaluated on the bases of insect infestation, plant foliage and fruit damage, and insect catch counts. Effectiveness of control was studied relative to distance from light traps. Traps were the only control measure used to protect the tomatoes from insect damage.

There was no appreciable difference in effectiveness of the three trap types tested. Fan traps collected and held a few more insects than did gravity traps, but the difference was not significant. Hornworms were more abundant than in 1963, with about 50 percent less parasitism. Hornworm-damaged ripe fruit increased gradually from 0.7 percent within 24 feet of the traps to 3.2 percent in an area 336 to 360 feet from the traps. Hornworm-infested tomato plants gradually increased from 49 percent within 24 feet of the traps to 67 percent at the greater distance. Foliage destroyed on plants near the traps was less than 0.1 percent of the total, and that on plants farthest from the traps was about 0.3 percent.

The population of corn earworm moths was much larger than in any year since 1959. Despite this large population, only 0.17 percent of 133,265 fruits

harvested within 372 feet of the traps was infested. Fruit infestation in unprotected plantings in the surrounding county area varied from 0 to 9 percent.

Cutworm infestation was uniformly about 6 percent throughout the test area. Although many cutworm moths were caught in the traps, no appreciable control was effected. Microscopic examination of exposed tomato halves showed no drosophila infestation in the lighted field.

This season's work indicates that tomato plants and fruit may be protected satisfactorily from hornworms and corn earworms by blacklight insect traps without the use of insecticides, and that blacklight traps will not adequately protect the fruit from cutworms.

Field studies were continued to determine the time of night that corn earworm, tobacco hornworm, and tomato hornworm flights occur. Corn earworm moths were active from about one-half hour before sunset to sunrise and were captured in equal numbers from 8 p.m. until daybreak. Tobacco and tomato hornworm moths were captured during all hours of the night, with catches greatest in the morning hours.

A new project was initiated (March 1965) in cooperation with Entomology Research Division, ARS, and the California Agricultural Experiment Station, Riverside to study electric light traps for use on cabbage loopers. An experiment in Riverside, California has been designed to determine whether female sex attractants can be used to increase the catches of male cabbage loopers in insect light traps. An experiment has been started in Mesa, Arizona, in cooperation with the Entomology Research Division, to determine the effectiveness of (blacklight) traps in catching cabbage looper moths, and to determine the dispersal of the moths in the field. Future tests will be run to develop equipment for optimum performance in the arid Southwest, and for effective use against a variety of species. Ultimate application of the equipment is to reduce or eliminate the use of pesticides wherever practical.

2. Electric Traps for Grain Insects

Cooperative studies with Purdue University were conducted to determine the responses of cereal leaf beetles to electromagnetic radiations and to determine whether light traps could be used to survey for this pest.

In laboratory studies, adult beetles approached both green and blacklight attractant lamps placed at the end of an 8- by 4- by 4-ft. chamber. None were observed in flight. An additional test indicated that cereal leaf beetles were not attracted to a 60-watt incandescent lamp.

Temperature was a critical factor influencing flight in both field and laboratory investigations. At 70° F. the insects crawled or hopped; at 75° and 80° they readily flew. In laboratory tests at 80°, 74 percent of the

beetles released were captured in traps using one 15-watt blacklight or one 15-watt green lamp as the attractant.

Field investigations were continued to determine the feasibility of using light traps to survey for cereal leaf beetles. Traps were installed in a heavily infested area in southern Michigan and in a lightly infested area in northern Indiana. Trials were inconclusive in Michigan because an insecticide application drifted several miles into the test area, killing most of the adult cereal leaf beetles and nullifying the endeavor. Only three beetles were caught in northern Indiana, with very few observed in the nearby area. After 2 years' investigation, results are still inconclusive but indicate that light traps will not be useful as survey tools for cereal leaf beetles until the insect pest spreads to a warmer climate.

European corn borers caused an estimated 50-million-bushel corn loss in Iowa in 1964, the greatest loss in 5 years. Light traps are useful in studies and in the control of corn borers by determining the time of emergence, the dates of maximum flight activity, the comparative activity from year to year, and the timing of insecticide applications. Light traps have been operated near Ames since 1952 in cooperation with the USDA European Corn Borer Investigations Laboratory and the Iowa Agricultural and Home Economics Experiment Station. The 12,535 corn borers captured in the four traps operated in 1964 was a 40-percent increase over 1963. The traps will be operated in 1965 with the same cooperators as in 1964.

3. Electric Traps for Cotton Insects

Laboratory and field studies relating to the use of visible and near-ultraviolet radiant energy for attracting and collecting various species of cotton insects were continued in 1964 at College Station, Texas. Studies were cooperative with the Texas Agricultural Experiment Station and the ARS Entomology Research Division Laboratories at College Station and Brownsville, Texas. The Physics Department, Texas A&M University, cooperated informally in certain phases of these studies. This project contributes to Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm".

In cooperation with entomologists of the Cotton Insects Systemic Chemicals Investigations, ENT, College Station, Texas, group response techniques and Y-shaped test chambers were used in spectral response studies with adults of the boll weevil (Anthonomus grandis Boheman), the bollworm (Heliothis zea (Boddie)), and the tobacco budworm (Heliothis virescens (Fabricius)). Work with the boll weevil using a single stimulus technique, ten different wavelengths in the 315- to 615-millimicron (mμ) region, and three stimuli energy levels confirmed previous test results showing a response peak in the blue-green region at approximately 500 mμ. No shift in response peak was apparent within the range of intensity levels tested.

Work on attractance of bollworm and tobacco budworm moths to radiant energy has revealed the need for testing techniques which will better evaluate

differences in moth response to specific wavelengths. Emphasis in laboratory work has been shifted to studies with the bollworm and tobacco budworm. No further laboratory work with the boll weevil is planned at the present time. Information resulting from these action spectral studies will provide a basis for specifying emission requirements of an efficient attractant lamp for the bollworm and tobacco budworm.

Work has continued in cooperation with biophysicists of the Physics Department, Texas A&M University, in developing techniques and equipment for electroretinogram (ERG) studies with insects. An ERG study has been made of the spectral sensitivity of the compound eye of the boll weevil. The spectral sensitivity curve indicates there are two distinct regions of peak sensitivity. One peak is at 518 mμ and the second at a point yet to be determined in the ultraviolet. In carrying out this study, an effort was made to develop equipment and techniques which are adaptable to most insects. The next phase of this work will be ERG studies with the bollworm and tobacoo budworm. Similarity of results obtained with the boll weevil by group response and ERG techniques indicates some promise for utilizing ERG response determinations as a means of predicting phototactic responses of insects to radiant energy stimuli.

Limited studies on the response to light of the boll weevil were continued in cooperation with the Entomology Research Division, ARS at the Boll Weevil Research Laboratory, State College, Mississippi. For purposes of establishing standard testing procedures, tests were conducted on the effects of numbers of weevils per test, dark prepa[illegible]on period, exposure time, and intensity on the response of the insects. Results indicate that weevil response decreases as the number of weevils per test increases. Intensity appears to influence weevil response favorably as it is increased.

More tests are necessary for conclusive results, and work will be continued to establish these factors.

4. Electric Traps for Tobacco Insects

Research on use of light traps for attracting and controlling tobacco insects was continued at Blacksburg, Virginia in cooperation with the Virginia Agricultural Experiment Station, and at Oxford, North Carolina in cooperation with the Entomology Research Division, ARS, and the North Carolina Agricul[illegible]cal Experiment Station. A new project was also established late in the year at Lexington, Kentucky, where cooperative studies will be conducted with the Kentucky Agricultural Experiment Station.

Investigations on the effectiveness of insect light traps covering large areas for the control of tobacco insect populations were continued during 1964 at Oxford, North Carolina. The circular area covered by traps was increased from a 6-mile radius (113 sq. miles) with 366 traps to a 10-mile radius (314 sq. miles) with 1,079 traps. Gravity-type traps with blacklight lamp attractants at a density of approximately three per square mile were installed in the 200-square-mile annular area around the original circular

area. Gravity-type traps in the inner 50-square-mile circular area (4-mile radius) were replaced with fan-type traps at a density of about 5.5 traps per square mile. The change in trap type and increase in trap density were made to study possibilities of controlling insects with smaller wingspread than that of the hornworm moth. Check traps were extended to 20 miles from the center of the area in north, south, east, and west directions. Installation of traps was not completed until mid-August.

The mean catch per trap, hornworm damage to tobacco, the number of hornworm eggs laid on tobacco, and the number of budworm larvae on tobacco plants were lowest at the center of the trapped area and increased as the distance from center increased. The estimated reduction in hornworm population between 12 miles from the center and the center was 77 and 75 percent for males and females, respectively, as compared to 94 and 64 percent, respectively, in 1963. The estimated population reduction between 20 miles from center and the center was 89 percent for both sexes. The reduction in plants damaged by budworms in the untreated tobacco fields between 12 miles from the center and the center was 57 percent in 1964.

Inconclusive results were obtained from farmer cooperative area control investigations in cooperation with the South Carolina and Kentucky Agricultural Experiment Stations. Lack of sufficient area coverage or desired trap functioning may have influenced results.

At Chatham, Virginia, field investigations were continued to determine the time of night during which insects are most active. Some indications were obtained that the activity is greatest during early evening hours. For moths, in general the activity increased again prior to dawn. An observation was made that insects considered to be nocturnal were captured in light traps during daylight hours with lamps energized.

At Blacksburg, Virginia, encouraging results have been obtained from preliminary electrophysiological studies on tobacco hornworm moths. This work will be intensified in an effort to determine the characteristics of the radiant energy that are most attractive or repulsive to tobacco insects.

Plans for the 1965 season include studies to improve trap design, extension of check traps to 30 miles from the center in the Oxford experiment, tobacco insect migration studies near Cape Hatteras, North Carolina, shade-tobacco insect control studies in Quincy, Florida, and area population control investigations on St. Croix, Virgin Islands, all in cooperation with Entomology Research Division, ARS.

St. Croix will be used by Entomology and Agricultural Engineering Research Divisions as an isolated field laboratory for testing effectiveness of electric insect traps and other insect control measures.

During the past year, approximately 2.6 PMY were devoted to these projects since new men were added during the year. With the addition of a man on St. Croix, this will be increased to 4 PMY.

B. Components and Design of Electric Insect Traps for Survey and Control

Participation in activities under North Central Regional Project No. 67, Migration of Aphids and Noctuids, at Lafayette, Indiana, proved effective in expanding the use of blacklight traps for survey. The purpose of this project is to determine the causes, the pathway, and the time of aphid and corn earworm migration. A southwest to northeast appearance of the first corn earworm moths along the major drainage systems corroborated findings of 1963. The percentage of field corn infested seemed to be directly related to the number of moths captured by traps. Early isolated catches indicated some overwintering in Indiana. Studies of moths caught at Lafayette, Indiana indicate that over half the moths collected in August could have been migrating.

Data on presence and abundance of 18 economic species of insects were determined and reported from the traps used in the NC-67 survey system. Collections in various parts of the State provide valuable information to extension workers and farmers as to the need for and time to apply chemical controls.

Cooperative activities with Plant Pest Control Division were continued. A new 6-watt light trap was designed for dual-purpose use in both general survey operations and European chafer detection. Eighty-four such units were obtained and operated satisfactorily during the 1964 season. Inverter power supplies for operating these traps from storage batteries were also improved to make them capable of operating either 6- or 15-watt lamps and to increase dependability of starting. Electric traps aided in the detection of a substantial infestation of European chafer in the area of Erie, Pennsylvania; so expansion of survey activities into Ohio is planned in 1965.

A cooperative test with Entomology Research Division of the usefulness of light traps in studying the flight habits of codling moths was conducted in orchards near Yakima, Washington. The traps proved more efficient and dependable than conventional bait traps and captured a more representative sample of the moth population. Further investigations are planned, including possible use of light traps for control.

Promising results were obtained with light traps of special design for attracting and collecting boll weevils. Traps were designed to take advantage of the intrinsic negative geotactic characteristic of boll weevils and were equipped with experimental strontium-blue lamps. The peak emission of these lamps is at approximately 500 mμ, the region of peak boll weevil response as indicated by laboratory test results. Over 100 weevils were collected in field trials of these traps during the period July 8 through September 30, 1964. Limited observations indicated that weevils were attracted primarily during early evening (1700-2000) and early morning (0500-0800) hours. Female vs. male ratio of trapped weevils was 1.7. Further study of trap design is needed in order to fully evaluate the possibilities of using light traps as a survey tool for boll weevils.

A compact trap of commercial origin was evaluated for possible use as a general purpose survey trap. The trap, equipped with a 6-watt blacklight (BL) lamp, was found to be nearly as effective for attracting and collecting bollworm moths as a conventional survey trap equipped with a 15-watt BL lamp. The survey trap with the 15-watt BL lamp proved more effective for cabbage loopers and for insects in general as evaluated by weight comparisons of catches. Further investigation of compact type survey traps appears warranted due to reduced power requirements, an important consideration from the standpoint of battery-operated units.

Sample preparation was studied as a means of improving sampling accuracy of a grain-type sample divider. The divider was evaluated in 1963 and found to be a useful tool for reducing time and labor requirements for identifying and counting insects in survey trap collections. No improvement in sampling accuracy resulted from (1) one division or mixing of insect collection prior to sampling; (2) two divisions or mixing prior to sampling; or (3) one division or mixing after each sub-sample. These results indicate that further improvement in sampling accuracy can be expected to result only from design improvement of the sampling device.

In an effort to improve trapping efficiency, a survey trap was equipped with circular disc louvers in such a manner that lamp radiation was shielded from the ground for a 10-ft. radius about the trap. This design was used in order to eliminate reflected radiation from ground and foliage near the trap as a secondary and possibly significant competing attractant. Evaluation based on catches in the trap with and without louvers showed the louvered trap caught fewer numbers of bollworms, cabbage loopers, and cotton leafworms, but differences were not significant. The louver trap design principle was not adequately evaluated by this test since no record was made of the relative numbers of insects on the ground near the traps which were compared.

An experimental 15-watt strontium-blue fluorescent lamp (developed by the General Electric Co. for use in boll weevil attractancy studies) was evaluated as an attractant lamp for survey purposes in tests at College Station and at Brownsville, Texas. Strontium-blue lamps were compared with Philip's phosphor BL lamps. The data from both locations indicate the strontium-blue lamp is possibly more attractive to coleoptera than the BL lamp and less attractive to lepidoptera.

Work will continue on the development of efficient light traps for insect survey purposes.

C. Physical Methods for Fly Control

Investigations of physical methods for controlling flies around dairies were continued at Beltsville, Maryland, in cooperation with the Animal Husbandry and Entomology Research Divisions, ARS.

The effectiveness of electrocutor-grid screens placed in windows plus an indoor electrocutor trap with blacklight lamps for controlling fly populations was evaluated in two calf barns where large numbers of house flies and stable flies were present. Although many flies were killed by the grids, no substantial reduction of the fly population within the grid-screened barn could be measured unless all major openings were closed or screened. When the animals were allowed access to exercise lots through open doors, the fly populations in the test barn and the "check" rapidly equalized.

Outdoor behavior of face flies was studied, both on herds in the field and on a single animal confined in a cage with a known fly population. Only a small proportion, 10 to 15 percent, of the total face fly population actually annoys cattle at any given time. Voluminous records were taken on the visits of individual flies to the animal in the outdoor cage in an effort to determine "typical" visiting behavior patterns. Analysis of the data is not complete, but some characteristics were apparent: Female flies visit the animals much more frequently than males, but males do cause some annoyance. The number of flies present on cattle is most closely related to the activity of the animals, with the greatest annoyance when the cattle are resting quietly. Although flies visit the face most frequently, they do rest on other parts of the body in considerable numbers. An evident peak of activity of released colonized flies occurred early in the morning, but activity of wild flies appeared more evenly distributed throughout the day. All flies leave the cattle at dusk while natural light levels are still quite high.

All these characteristics indicate the advisability of further investigating control measures which affect face flies when they are off the cattle.

Additional studies of the nocturnal habits of face flies confirmed that they rest on the foliage of trees at night. Although the flies are readily attracted (about 80 percent) to "blacklight" ultraviolet in confined spaces, those found resting on foliage at night do not respond in this manner. Electrocutor-grid traps with blacklight lamps placed in trees attracted less than 1 percent of a released population in 48 hours. Investigations of the factors affecting this change in behavior may provide information useful in control.

Laboratory tests of the mating activity of face flies indicate that sterilized males compete effectively with normal males in mating. Also, females appear to mate only once if they are inseminated during their first mating. Examination of females observed attempting to remate, only 5 to 10 percent of all females, revealed that they had not received any sperm during their first mating. This characteristic indicates that use of sterilized males should be effective in preventing reproduction. A laboratory trial using a ratio of eight sterilized males to one normal male to one female resulted in a 94 percent reduction in pupae.

Additional tests of the responses of face flies to monochromatic light confirmed that blacklight ultraviolet is highly attractive under conditions of confinement and that wavelengths in the red and yellow spectral regions are unattractive. Refinements of the testing procedure and methods of data analysis are being made in an attempt to more clearly establish differences in attractiveness.

D. Radiofrequency and Glow-discharge Equipment for Insect Control and Treatment of Seed and Plant and Animal Products

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination have been continued. Investigations were directed toward developing basic information and evaluating possible agricultural applications. The research is cooperative with the Departments of Agricultural Engineering and Entomology at the Nebraska Agricultural Experiment Station. Substantial cooperation has also been provided by Crops Research Division, ARS, USDA; the Asgrow Seed Company; the Agricultural Engineering Departments of the University of Idaho and Texas A&M University; and others.

1. Grain and Forage Seed Treatment and Insect Control Studies

Previous studies have shown that all developmental stages of all stored-grain insects studied can be killed by exposure for a few seconds to RF fields of sufficient intensity. Such treatment does not damage the wheat for germination or milling and baking purposes.

Last year equipment was constructed to pulse-modulate the output of the RF power oscillators in efforts to improve the efficiency of the method for insect control. Extensive studies were conducted this year to determine the most effective combinations of pulse repetition rate, pulse width, and field intensity. With pulse modulation, field intensity can be nearly twice that possible with continuous oscillation, but anticipated increases in insect mortality were not achieved generally. Pulse modulation did increase the mortality of lesser grain borers treated in wheat, however. Comparison of continuous and pulse-modulated treatments will be continued for different stored-grain insect species.

Studies were continued in cooperation with the Department of Entomology, University of Nebraska, in efforts to explain physiological effects of RF treatment on insects. Changes in weight loss and respiration following treatment were observed for yellow mealworm larvae which were exposed to sublethal treatments. Protein synthesis has been studied as a measurement of metabolic activity by incorporation of radioactive amino acids.

Electron microscopy studies on tissue from wax moth larvae revealed vacuolation in nerve cells in RF-treated insects which was not evident in untreated insects.

A pilot plant for continuous-process RF treatments was constructed this year. Initial results verified the exposure levels needed for stored-grain insect control which were previously determined in the laboratory with small samples.

Earlier studies have shown that RF treatments are effective in reducing the percentage of hard seed in alfalfa, red clover, ladino clover, and sweetclover. Infrared and RF treatments were compared this year on more sweetclover seed lots containing high hard-seed percentages. Both treatments reduced hard-seed content and provided a corresponding increase in germination. Both treatments were more effective when the seed moisture content was low. Twenty-seven alfalfa seed lots with high hard-seed content were collected from the Pacific Northwest and treated to learn how commercial seed lots will respond to RF treatment for hard-seed reduction. Treated samples are now being tested for germination.

Low germinating seed lots of Indian ricegrass and Cicer milkvetch were exposed to RF treatment, but the treatments employed were not effective in increasing germination.

At Pullman, Washington, sweetclover seed samples at nine moisture contents ranging from 2.0 percent to 15.4 percent were irradiated in the glow-discharge chamber. Results indicated that the seeds could withstand a higher level treatment with each successively lower moisture content. Any reduction in hard-seed content in samples with higher than 4 percent moisture was accompanied by an increase in the number of dead seeds. At lower moisture content, treatment levels were found which increased the germination percentage by reducing the hard-seed content. Studies on sweetclover seed will be continued.

A continuous-treatment glow-discharge chamber was used to irradiate alfalfa seed samples. Data obtained indicated that a significant reduction in hard-seed content could be accomplished in 30 seconds or less. The repeatability of results was not good. Temperature data were collected for various treatment conditions and attempts to correlate those with treatment results will be made.

Equations were written which related treatment temperatures to current, absolute pressure, and length of treatment for alfalfa seed in the batch-type glow-discharge chamber. Maximum treatment temperature was found to be a reasonably good criterion for predicting significant reduction of hard-seed content in alfalfa. For seeds at 6 percent to 9 percent moisture a maximum temperature of 75° C. to 85° C. produced good results. Seeds at approximately 2 percent moisture were able to withstand about a 30° C. higher maximum temperature without a reduction in viability.

2. Vegetable Seed Studies

In previous cooperative research with the Asgrow Research Center, Twin Falls, Idaho, RF treatments have accelerated germination of spinach seed and

increased germination in seed lots of garden peas and beans containing hard seeds. Glow-discharge radiation reduced the hard-seed content of Kentucky Wonder beans. Acceleration of spinach seed germination was observed for the third consecutive year in tests this year which involved RF treatment of three different seed lots. Other seed treated included cabbage, cantaloupe, cucumber, eggplant, lettuce, onion, pepper, and tomato, but significant improvements were not obtained with these seeds this year.

3. Cottonseed Studies

In tests at Knoxville, Tennessee on cottonseed containing a high percentage of hard seed, audiofrequency glow-discharge treatments increased germination at 2 days from 24 percent for the control to 83 percent for the best exposure. A field test using Empire WR machine-delinted cottonseed at Knoxville did not reveal any improvement in germination or yield of cottonseed due to electrical treatment. Significant increases in yield however were observed in cooperative experiments with Texas A&M University for one treatment of Empire WR and Lankart SEL cottonseed. RF treatment also accelerated emergence and increased the yield for the Empire WR variety.

4. Soybean Studies

In cooperation with the University of Tennessee Department of Agronomy, Lee soybeans were planted in a field test. Three levels of treatment and a control were replicated six times in a randomized experiment. Time and pressure were held constant at 5 minutes and 3 mm Hg, respectively. Current levels were 20 ma, 40 ma, and 80 ma. No significant increases in early germination, total germination, and yield were caused by treatment. The test will be repeated in 1965 using different levels of current than used in 1964.

Results of analyses on oil from treated soybeans showed a trend for the oil from the treated beans to oxidize more rapidly than the control sample. there were large variations between replications, and the method used in extracting the oil was the suspected cause. A different method will be used for future experiments.

5. Dried Egg, Salmonella Studies

Experiments at Pullman, Washington on the effects of glow-discharge radiation on Salmonella were continued. To minimize the effects of temperature on the bacteria, the irradiation chamber was packed in dry ice during treatment. Temperature measurements made inside the chamber indicated that complete destruction of the organisms was obtained at temperatures less than 30° C. These results indicate that temperature alone was not the cause of destruction. Further studies will be conducted.

6. Characteristics of the Electric Glow Discharge

The emission spectra of the glow discharge at wavelengths from 200 millimicrons to 15 microns were obtained for an empty chamber and a chamber containing alfalfa and sweetclover seeds at high and low moisture contents at Pullman, Washington. The presence of seeds in the chamber caused the emission energy generally to decrease. The decrease was more pronounced with seeds at a higher moisture content. No shifts in wavelengths of peak emission were noted due to the presence of seeds.

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AREA NO. 12: ELECTRIC EQUIPMENT FOR FARM LABOR REDUCTION

Problem: American agriculture produces about 600 million tons of crop and animal products each year. This is more than five times the weight of the total annual steel production in the United States. Most of these products are handled several times, which means a tremendous task of moving material. Development of equipment to decrease labor of livestock chores has been far less rapid than development of field equipment. For example, the production per man-hour for all crops increased an estimated 463 percent during the last 50 years. This increase is more than twice that for all livestock, 227 percent. The amount of working time spent on livestock other than horses and mules (estimated to be 3,282 million man-hours per year in 1964) is 39 percent of the entire farm labor requirement. Equipment to substitute electric energy or tractor power for hand labor for many farmstead operations is now on the market but research is needed to provide flexibility of use in existing buildings and to permit automatic control as well as to extend mechanization to other operations. Because livestock chore equipment may be needed 365 days per year, it should pay for itself more quickly than field equipment which may be used only a few days per year. Increased emphasis on automatic materials handling equipment by livestock producers and equipment manufacturers has caused them to obtain advice and counsel of research workers. A continuing aggressive research program is essential to meet the developing needs of this segment of our national economy.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program with engineers working at Beltsville, and cooperatively with state experiment stations, USDA apiarists and other scientists on basic and applied research. Equipment and control for automatic feeding of livestock and poultry is under development at the Washington and Illinois State Experiment Stations. Work on performance characteristics of upright-silo unloaders is in cooperation with the Minnesota State Experiment station. Work on equipment for handling bees and honey is in cooperation with the Apiculture Branch, Entomology Research Division, and the Arizona and Wisconsin State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 4.5 professional man-years; of this number 2.0 are devoted to bee equipment; 2.0 to equipment for livestock and poultry; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The agricultural experiment stations of many of the States have research underway whose major objectives involve the obtaining of information on the uses to be made of electrical energy to reduce labor, increase production and improve family living conditions. In the design of these studies provision has been made to develop and investigate new equipment and explore the possibilities for new uses for electricity on the farm and in the home.

Many of the projects are concerned with the varied problems of chore labor mechanization and an expansion of the use of electricity for ventilating, heating, lighting and cooling under the various production enterprises of today's farming operations. Development and testing of prototype specialized equipment for product collection, processing, packaging, and transport, as well as crop storage, loading and unloading devices, are a part of the overall program of investigations.

Much of the research is conducted cooperatively with the Department.

A total of 9.7 professional man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Cattle Feeding Equipment

In Illinois, work cooperative with the University of Illinois Agricultural Engineering and Animal Science Departments has resulted in the development of the satisfactory two-position automatic silo unloader control for upright silo unloaders. The two-position control utilizes a silicon control rectifier which can modulate the speed of an AC-DC motor that powers the silo unloader winch. A current transformer in the silo unloader motor circuit supplies a DC signal to the gate circuit of the rectifier to modulate the speed of the winch motor. With a maximum lowering rate of approximately 4 inches per minute, a delivery accuracy of 89 percent or better can be expected. This control system is economical. It uses readily available commercial components and can result in more satisfactory operation of the silo unloader than with manual controls.

In Minnesota the performance characteristics of electric motors for the operation of silo unloaders is being determined in cooperation with the University of Minnesota Agricultural Engineering Department.

During periods of sustained low temperatures freezing of silage in upright silos occurs. Starting at the wall the freezing progresses toward the center. The width of the frozen band depends upon the prevailing temperatures, the diameter of the silo and the nature of the silage material and its moisture content. Although knives are added to the gathering augers of unloaders it is generally known that output rates are reduced during the winter months.

Daily delivery rates were determined for two unloaders for a period of two months. The results indicate reduced output rates up to 50 percent at temperatures below -10° F. The reductions would not be as great in larger diameter silos with a greater heat mass and in which the frozen area represents a smaller part of the surface area.

A cooperative project with Washington State University Agricultural Engineering Department on the development of the automatic trench silo unloader has not been active during the past year because of the absence of professional personnel to direct the project.

B. Hog Feeding Equipment

The cooperative research with the University of Illinois Agricultural Engineering Department has resulted in the design and field testing of a successful medium-pressure pneumatic conveying system for use with small feed grinders. The use of the patents for this device has been licensed to several manufacturers by USDA. One manufacturer produced two prototypes during 1964 and plans to produce five prototypes during 1965. Assistance has been given to manufacturers in the design of commercial models. A redesigned mill and conveyor system was placed on test in March 1964 on an Illinois farm. In March 1965 it had ground over 1600 tons of feed in nearly 1200 hours of use. Only one weak point was shown in the conveyor during this period of operation. Abrasion of the auger injector resulted in wearing through the injector tube. Thicker metal in this area will overcome this problem.

C. Apiary Equipment

A cooperative project with the Apiculture Research Branch of the Entomology Research Division and the Agricultural Engineering Department, University of Wisconsin, Madison, Wisconsin, is the development of equipment for the mechanization of the collection and extraction of honey. An electrically heated vibrating type uncapping knife has been successful. The temperature of the knife is controlled by a thermistor temperature regulator. A system for heating the knife directly by passing a high current through the blade is being developed.

A two-thermostat control system on a cappings separator has performed satisfactorily. Additional data on the performance of the unit during long and short idle periods and at varying capacities is needed.

The use of a high velocity air blast has been very effective for removal of bees from supers prior to bringing the supers into the honey house.

In a cooperative project with the Apiculture Research Branch of the Entomology Research Division and the University of Arizona Agricultural Engineering Department, Tucson, Arizona, work is continuing on the development of an efficient and continuous process for honey extraction. Plastics are being thoroughly investigated for use as honeycomb as part of this system. Twenty types of plastics with six cell sizes were tested in 1964-65. The smallest cell size (11/64 in.) was used to a limited extent only. Color has no effect on acceptance of a particular plastic by the bees. Soft plastics were less used than others.

A new chisel point uncapping roller was constructed and tested by commercial honey producers. The rollers performed satisfactorily.

The 50-watt thermo-electric heat pump which provided a cold plate surface in the bee hive was not effective in reducing the hive temperature, an important

feature of bee management in the Southwest. Evaporative cooling as a means of reducing colony temperature was more satisfactory and resulted in a 59 percent increase in honey production.

D. Poultry Equipment

Equipment was designed and custom built to record automatically the time of egg lay for 1000 birds in individual cages. This is the first known automatic recording trap nesting unit built in the United States. This equipment will be used to obtain detailed records for computer analysis on individual birds at the Beltsville Research Center.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Cattle Feeding Equipment

Daum, D. R. and Puckett, H. B. 1964. A control for unloading and loading silos automatically. Illinois Research. Univ. of Ill. Agr. Exp. Sta. Fall. 2 pp.

Apiary Equipment

Detroy, B. F. 1964. Factors relative to heat transfer characteristics of honey conditioning devices. Univ. of Wis. Memorial Library.

Owens, C. D. and McGregor, S. E. 1964. Shade and water for the honey bee colony. Leaflet No. 530. July.

Owens, C. D. and Detroy, B. F. 1965. Selecting and operating beekeeping equipment. Farmers' Bulletin No. 2204. January.

AREA NO. 13: ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

Problem: Research has shown that temperature, light, space, and other environmental factors affect the growth, health, fertility, production, and feed consumption of farm animals. Thus, savings in feed, reduced losses from disease and exposure, and decreased costs of production may justify many environmental improvements. Special, controlled environments are necessary for the proper conditioning of crops like tobacco, sweet potatoes, grain, and peanuts; and are extremely effective in maintaining the quality of stored fruits and vegetables. Current scientific and economic developments indicate that production of vegetables and flowers in the future may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops. Conditioning and safe storage of high-moisture grain are major problems for a great many farmers. Use of solar heat to aid in drying offers potential economy in this operation. The lack of available electric energy in remote areas of a farm has limited the use of electric devices. Conversion of solar to electric energy at the site for adapting new and more efficient thermoelectric devices to farm application may eventually eliminate this energy shortage.

USDA AND COOPERATIVE PROGRAM

A program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with the Crops Division on basic studies of light and thermal environment and their relation to plants in growth chambers. A basic and applied program of solar energy collection and storage for grain drying is underway in Kansas, in cooperation with Kansas State University. Research on equipment for basic and applied studies involving light and thermal environment for poultry is underway at Beltsville in cooperation with the Poultry Branch, Animal Husbandry Research Division. Basic and applied studies on the use of heat pumps to modify thermal environment for hog production is conducted at Holland, Virginia, in cooperation with the Virginia Agricultural Experiment Station.

The influence of electric equipment and environment on health and disease is being studied in USDA laboratories at Athens, Georgia. Equipment for the application of carbon dioxide to plants is under development at Pullman, Washington, in cooperation with the Departments of Agricultural Engineering and Horticulture of the Washington Agricultural Experiment Station and at Kansas State University in cooperation with the Departments of Agricultural Engineering, Horticulture and Physics. Studies on the performance of milk handling equipment are underway at Beltsville in cooperation with the Animal Husbandry Research Division and the Eastern Utilization Laboratory. Performance characteristics are being determined for turf soil heating with electric cable at Purdue University in cooperation with the Departments of Agricultural

Engineering and Agronomy of the Purdue Station; also at Beltsville in cooperation with the Crops Research Division; and at St. Paul, Minnesota, in cooperation with the Departments of Horticulture and Agricultural Engineering. Performance characteristics of equipment are being studied for maintaining environment for conditioning potatoes for processing. This work is in cooperation with the Departments of Agricultural and Chemical Engineering, Horticulture and Plant Pathology of the University of Minnesota and the Market Quality Research Division and the Transportation and Facilities Research Division, ARS, East Grand Forks.

The Federal scientific effort devoted to research in this area totals 6.0 professional man-years; of this number 2.7 are devoted to plant environment equipment; 0.5 to solar equipment; 1.6 to poultry environment equipment; 0.2 to swine environment equipment; 0.5 to milk cooling equipment; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects that heat, light, space and other factors have on farm animals; soil, light and atmospheric conditions on plants; and temperature, humidity and gases on stored products. Special attention is being given to development of means for collection, storage and use of solar energy for structural heating and crop conditioning.

A great portion of this research is cooperative with the Department.

A total of 5.0 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Equipment for Poultry Environmental Studies

At Beltsville, in cooperation with the Poultry Husbandry Research Branch, the third year of a 5-year genetic selection of laying stock responsive to less than 24-hour day cycle (18 hours) was completed. A comparable control house was completed and used for birds housed on a conventional 24-hour day. Preliminary results indicate approximately equal production per season from birds on the 18-hour day as those on the 24-hour day.

Conditions maintained are 75° F. during light cycle, 65° F. during dark cycle and less than 75 percent relative humidity.

In Georgia, environmental facilities and instrumentation were designed and assembled to determine the effect of air velocity on the heat tolerance of

young chickens as indicated by body temperatures, respiration rates, and heartbeat rates. The equipment provided air velocities up to 570 fpm and temperatures up to 112° F.

Five different air velocities were maintained in one test and six air velocities in each of four additional tests, while the ambient temperatures were increased to maximum values ranging from 92° to 112° F. and then reduced to values near the original 68° to 88° F.

Increased air velocities were accompanied by longer delays in the rise of body temperature and respiration rate and smaller maximum values of these factors when the birds were subjected to increasing ambient temperature up to 105° F. The effect of air velocity on heart rate under the test conditions was not clear.

B. Equipment for Swine Environmental Studies

In cooperation with the Virginia Agricultural Experiment Station the study on buildings and equipment design for efficient swine production, including the utilization of heat pumps, has been continued. A summer test with Specific Pathogen Free hogs was conducted utilizing steel-slotted flooring in half of the environmental temperature-controlled buildings and in half of the semi-open house. Two pens of 15 hogs each were grown on the slotted floor and two pens of 15 hogs each on concrete floor in each building. On the steel-slotted floors the hogs' feet became tender and sore; however, the animals stayed cleaner and the floors were completely self-cleaned. As in previous tests, the average daily gains and feed efficiency data were not significantly different for animals in the two housing facilities. No difference in carcass quality analysis has been noted for hogs grown under the various test conditions in six trials. Hams from last trial are being cured under standard Smithfield procedures. These will be taste-test evaluated.

It has been concluded, on the basis of the data from six trials, that under the prevailing climatic conditions optimum temperature controlled housing was ineffective as a means of increasing swine growth rate and/or feed efficiency.

C. Milk Cooling Equipment on Farms

Experiments are being carried on to determine the minimum requirements for cooling capacity and operating conditions to accomplish sstisfactory storage of raw milk for every other day pickup. The trials so far completed have been made on a 600-gallon ice-bank-type commercial farm tank, filled to near capacity with four successive milkings from animals in a research dairy herd at the Agricultural Research Center, Beltsville, Maryland. The rate of cooling of the milk has been varied experimentally by imposing an intermittent operating cycle on the cooling water circulation pump. Periodic samplings of the mixed milk are analyzed for free fatty acids as an indication of hydrolytic rancidity, for microbial growth, and for flavor deterioration.

Results indicate that for a raw milk supply of high initial quality, a cooling rate sufficient to bring the milk to 50° F. in two hours after milking is completed may be sufficient to maintain its quality. When the cooling time is increased to about four hours, bacterial multiplication can be demonstrated, although neither hydrolytic rancidity nor flavor deterioration are detectable.

Similar experiments will be conducted with lower quality raw milk. About 0.5 professional man-year is required for this study.

D. Plant and Product Environmental Equipment

1. Carbon Dioxide Control in Greenhouses

The study of the engineering problems involved in the measurement and control of the carbon dioxide concentration in an air-supported plastic greenhouse was continued at Pullman, Washington. The research was in cooperation with the Agricultural Engineering and Horticulture Departments of the Washington Agricultural Experiment Station, Washington State University.

A fourth air-supported greenhouse was constructed to provide a means for more rapid collection of plant data.

Two control systems, designed during the previous year to control carbon dioxide (CO_2) concentration in relation to available light intensity, were laboratory tested. One system used a controller which would vary the CO_2 concentration while the second provided for a constant level control of CO_2. The first system showed greater promise and was tested in a greenhouse. The system used the amplified difference in voltage output of a solar cell and the infrared analyzer to drive a valve open or closed thereby adjusting the CO_2 concentration in relation to light intensity. Tests conducted comparing the light adjusted control system to the previously developed constant concentration system indicated a savings in CO_2 consumed could be obtained.

Crops of okra, lettuce and radishes were grown under controlled CO_2 concentrations of 400, 800, 1200 and 1600 parts per million (ppm). The vegetative growth of lettuce and okra was increased with each successive level of CO_2. No significant increase in root weight of radishes was noted above the 1200 ppm level; however, there was an increase in the root-to-top weight ratio with each increase in CO_2 concentration.

To study the effect of time and duration of CO_2 additions, crops of lettuce, radishes, peas and spinach were grown under the following time-concentration regimes: 1200 ppm, 6 a.m. to 6 p.m.; 1200 ppm, 9 a.m. to 3 p.m.; and 1200 ppm, 6 a.m. to 9 a.m.; and 3 p.m. to 6 p.m. The data showed that CO_2 addition during the mid-day period was the most effective in stimulating plant growth. Crops of radishes and peas were grown under the following conditions: 1200 ppm, 6 a.m. - 6 p.m.; 1800 ppm, 9 a.m. - 3 p.m.; and CO_2 concentration adjusted to light intensity. Data showed that yields in the light adjusted

house were higher than in the 1800 ppm, 6-hour house and about as good as in the 1200 ppm, 12-hour house. Less CO_2 was required in the light adjusted house than in the other two houses.

In cooperation with Kansas State University, equipment and controls were developed to spray carbonated water on leaf lettuce in greenhouses. Approximately 300 percent yield increase occurred when carbonated water was applied as mist 6 seconds out of every 6 minutes from 9 a.m. to 2 p.m. on clear days only. During the 45-day test 0.217 pounds of CO_2 was applied per gallon of water mist.

2. Plant Growth Equipment and Techniques

At Beltsville, in cooperation with the Crops Research Division, small, commercial plant growth chambers were modified in design and performance to improve lighting and air flow. Various combinations of fluorescent and incandescent light sources have been used to determine relative effects of light, radiation, and temperature. The use of continuous, perforated plenum chambers for air flow appears to be advantageously increasing the uniformity of growth patterns in the chamber.

Prototype small chambers, suitable for researchers and students, have been constructed. The units are portable with minimum controls. Plans and detailed instructions for these units will be issued after additional testing and use.

Continuous recorded measurement of actual plant growth has been expanded to indicate growth in both horizontal and vertical directions with an enlarged measurement system. The use of this equipment has permitted observation of cessation of physical growth when the dark cycle of plants is interrupted. Other controls have been designed to replace manual-switching lighting for special cycles. The designed unit is capable of controlling 30 lighting circuits with almost any combination of cycles.

3. Electric Equipment for Soil Warming for Plant Growth

Investigations were continued in Indiana, and initiated in Maryland and Minnesota, to determine the requirements for installation and management of electric soil-heating cable systems to maintain suitable turf conditions for activities in critical-use areas during cold weather. In Lafayette, Indiana this work is cooperative with the Purdue University Agricultural Experiment Station through the Agronomy and Agricultural Engineering Departments.

Cold season soil warming has become eligible for acceptance as a part of turf management programs. Heat applied to the root zone of bluegrass plants altered the natural temperatures in which the turf existed, thereby keeping the soil from freezing, promoting root growth and blade extension, keeping turf greener, helping sod knit, and melting snow. The effectiveness of heat treatments was evaluated considering electric energy used, temperatures, turf condition and turf growth. Five heated plots and an unheated control area

were studied. Each plot was 10 x 120 feet separated by 10 feet of unheated area. The study was conducted in the Purdue University varsity football practice field.

The warmest heated area did not freeze or crust during the 1963-64 winter. The control area was frozen 50 days during January, February and March of 1964. Two heated areas, each sustaining healthier areas than the warmest area, were frozen only 4 and 9 days during this interval. Control area temperatures averaged about 20° colder than the warmest treatment. Active growth, evidenced by blade and root extension, was observed during the entire winter months on the warmest heated area. Two of the intermediate level heated areas sustained healthy, vital, green turf during the winter months, but not active growth. In the remaining two treatments the turf grew later into fall and began growing earlier in the spring than the unheated areas.

Air temperature was found to be the best indicator of when heat should be applied. Temperatures in the soil defined the heat reserve and soil thermostats were used as limit switches to maintain the desired soil warmth. Use of time clocks allowed inclusion of off-peak electrical demand considerations.

Installations were made at Beltsville, Maryland and St. Paul, Minnesota, in order to study the effectiveness of soil heating in locations that have different winter weather conditions.

4. Environmental Equipment for Potato Conditioning

In Minnesota cooperative research is to determine equipment requirements to produce optimum storage of potatoes for processing.

Red River Valley potato processors could use local potatoes up until the month of September. This calls for refrigeration equipment to maintain proper temperature levels starting in April and continuing on through August.

Studies parallel to this project have established the desired storage temperature levels at 40, 45, and 50° F with relative humidity levels of 80 to 85%.

The equipment studies under this project provide the following data for design purposes:

1. Storage structures are to be tight and well insulated.

2. Refrigeration load for Red River Valley Area = 1 Ton of refrigeration per 100 Tons potatoes. Structure heat gain must be added. Cooling coil capacity = 1/3 of the normal rating at 10° F difference in temperature, air to refrigerant. This increased size of cooling coil may lead to use of humidification equipment on smaller coils.

3. Variety differences are apparent when evaluating response to storage conditions and recommendations for each are to be made on basis of physiologist's studies.

E. Solar Equipment

1. Solar Home Heating Equipment

In Kansas a solar-supplemented, air-to-air heat pump system was investigated while operating in a rural residence for 4 years. Two vertical south-facing plastic-covered solar collectors totaling 600 square feet were designed and used in the study. An underground storage system of 50 cubic yards of crushed limestone was also used in the system. Effectiveness of the system varies yearly depending upon the weather, but in general the heating capacity of the heat pump was increased 10 percent. The coefficient of performance and efficiency increased slightly less than 10 percent because of the additional energy consumption of the added fan motors. This project is currently being phased out.

2. Solar Grain Drying Equipment

Solar grain drying equipment was been developed in Kansas. Equipment using plastic collapsible solar collectors and fans used only 40 percent as much electric energy for fan operation as a system using fans without solar collectors.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Equipment for Poultry Environmental Studies

Drury, L. N., Brown, R. H., and Driggers, J. C. 1964. Cooling poultry houses in the southeast. Ga. Agr. Exp. Sta. Bulletin NS-115. May.

Plant and Product Environmental Equipment

Barrett, J. R., Jr. and Daniel, W. H. 1965. Electrically warmed soils for sport turfs - 2nd progress report. Midwest Turf News and Research, Leaflet No. 33. March. 6 pp.

Downs, R. F., Norris, K. H., Bailey, W. A. and Klueter, H. H. 1964. Measurement of Irradiance for Plant Growth and Development. Proc. of the American Society for Horticultural Science. Vol. 85, June 2.

Matson, W. E., Pettibone, C. A., Ackley, W. B. and Haynes, G. D. 1964. Control of carbon dioxide content in an air supported plastic greenhouse. Washington Farm Electrification Committee Progress Report.

AREA NO. 14: FARM ELECTRIC SERVICE AND INSTRUMENTATION

Problem: Farms east of the 100th meridian used twice as much electricity in 1959 as they did in 1950 and three times as much as they used in 1945. Increased use has forced many farmers to rewire or partially rewire their farmsteads at considerable cost. In some cases farm buildings are rewired unnecessarily to meet requirements of the National Electrical Code (NEC), which does not allow for diversity in the operation of farm loads. Overloading of installed wiring results in poor equipment performance, energy losses in the wiring, and creates a fire hazard.

Transformers burn out or must be replaced due to overloading. There has been no good method of predicting when a transformer should be replaced and many power suppliers are faced with the problem of finding a simple, effective one. These problems are expected to become increasingly acute as farmers install additional electrical equipment such as house heating units, air conditioning, milk coolers, motors for feed processing and distribution, and irrigation pumps.

Today's technology in farming, as well as research, requires accurate instruments for measuring or monitoring processes such as grain and forage drying and plant and animal environment. Current agricultural research is especially dependent upon accurate instrumentation; some problems require completely new kinds of instruments. Studies are necessary to determine the accuracy and practicability of instruments for many kinds of agricultural measurements.

USDA AND COOPERATIVE PROGRAM

The Department has a program involving agricultural and electrical engineers to develop an improved method of estimating the maximum electrical demands of farms. This program is in cooperation with the Iowa Experiment Station, the Rural Electrification Administration, and power suppliers in Iowa, Montana, Minnesota, North Dakota, Wisconsin, Kentucky, and Alabama. Data on energy consumption and electric equipment used on farmsteads are analyzed to predict electric demands by farms situated under similar conditions. Variations in electric equipment due to different crops, farming enterprises and weather require that studies also be made in other areas. Data obtained in cooperation with members of the Farm Wiring Committee of the American Society of Agricultural Engineers are analyzed in demand studies and in developing and substantiating changes to the National Electrical Code.

At Beltsville a program is underway to develop and provide accurate, practical and sometimes complex instrumentation for specific program needs.

Federal scientific effort devoted to research in this area totals 2.8 professional man-years. Of this number 1.0 is devoted to energy distribution and farm electric demand; 1.5 to instrumentation; and 0.3 to program leadership.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The agricultural experiment stations of a few of the States have research investigations in progress studying the electric demands of farms and the major appliances used on farms in order to evaluate the effects of these demands on farmstead distribution systems. Exploration is also underway on the possibility of developing a safe distribution system for the farmstead using voltages which are higher than those currently allowed under the National Electrical Code.

Many of the studies are cooperative with the Department.

A total of 1.7 professional man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Energy Distribution and Demand

The 1962 National Electrical Code restricts the load that farm wiring systems may serve by requiring that feeders and services be large enough to carry all the connected load at one time. Electric demand studies headquartered at Ames, Iowa were conducted in cooperation with the Farm Wiring Committee of the American Society of Agricultural Engineers, the Edison Electric Institute, the National Rural Electric Cooperative Association and 113 power suppliers. Electric energy demands of 1055 buildings on 336 farms in 36 states were metered by the power suppliers. ARS engineers analyzed the data, and drafted new NEC sections. These changes were approved by the National Fire Protection Association and it is expected they will become part of the 1965 National Electrical Code.

One of the causes of service interruptions and low voltage on farms is that power suppliers are unable to economically determine the maximum demands of individual consumers and, therefore, the required sizes of transformers and secondary services. In cooperation with power suppliers, engineers from the Rural Electrification Administration, and the Iowa Agricultural and Home Economics Experiment Station, a low-cost procedure for estimating the maximum demand of farms is being developed. The procedure is based on multiple regression equations relating maximum demand to appliances and energy consumption.

Demand data from the National Electrical Code study were combined with data obtained specifically for the transformer sizing study. Analysis of the combined data showed that for the same energy consumption demands in Southern U.S. are significantly higher than in Northern U.S.

A relation between demand and energy consumption was developed for possible use of power suppliers in sizing transformers and secondary services and for comparing the precision of this relation with the more precise multiple regression relation. Since more accurate demand estimates result when data are

divided into strata according to energy consumption, new techniques were used to force the regression lines for the various energy-consumption strata to intersect.

A method was developed of expressing confidence intervals as a percent of the estimated demands rather than as a constant. Comparisons of the precision of demand estimates based on energy consumption with demands estimated from appliances and energy consumption indicate that the main advantage of the multiple regression procedure is to reduce the number of estimates with large errors.

B. Research Instrumentation

At Beltsville light trap lamps were compared by spectrophotometric laboratory methods with newly designed instruments to detect change in light output level or wavelength distribution after field use in insect attracting equipment. For lamps used continuously for 5 months each season for 2 years (10 months total) the spectral distribution shows little or no change but the total emission declined 15 to 20 percent.

Approximately 150 type BL fluorescent lamps were examined by spectrophotometric analysis. Suitable measurement procedures were developed to determine precision of measurement. Lamps were compared to radiant energy sources with calibration of the National Bureau of Standards. Replications of measurements indicate an accuracy of ±5 percent in respect to repeatability of measured values. Spectral energy determinations were established for 10-nanometer intervals for the continuous spectra. Instrument bandwidth was approximately 1.3 nanometers.

Line Project Check List -- Reporting Year April 1, 1964 to March 31, 1965*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-heading
AEa1	Weed, insect pest, & plant disease control machinery Program leadership	Beltsville, Md.		
AEa1-1 (Rev.#2)	Equipment for application of pesticides, defoliants, fertilizers and seeds from agricultural aircraft	Forest Grove, Ore.	Yes	3-G-1
AEa1-4	Develop equipment & techniques for application of insecticides & fungicides to crops by ground machines	Wooster, Ohio Forest Grove, Ore.	Yes	3-F-1
AEa1-6 (Rev.#2)	Aerial spray equipment for forest insect control	Beltsville, Md.	Yes	3-H-1
AEa1-11 (Rev.)	Equipment for the application of chemicals to the soil for control of soil pests	Wooster, Ohio	Yes	3-B-1
AEa1-12	Investigations of equipment & techniques for mechanical & chemical control of weeds in crops	Columbia, Mo. Ames, Iowa	Yes	3-D-1
AEa1-15 (sup.part AEc5-2)	Equipment for the above-ground application of agricultural chemicals in cotton	Auburn, Ala. Shafter, Calif. Lubbock, Tex. Stoneville,Miss.	Yes	3-E-1
AEa1-16 (sup.part AEc5-2)	Equipment for soil incorporation of chemicals for cotton pest control	Stoneville, Miss Shafter, Calif.	Yes	3-E-2
AEa1-17	New mechanical and/or physical methods for insect control on grain crops	Tifton, Ga.	Yes	3-C-2
AEa1-18	Developing equipment for practical control of insects on grain crops grown in the Southeast	Tifton, Ga.	Yes	3-C-3
AEa1-19	Detecting and measuring spray deposits on corn ears and silks	Tifton, Ga.	No	
AEa1-20	Mechanical methods of destroying fallen cotton squares	State College, Miss.	Yes	3-E-3
AEa1-21	The development & evaluation of equipment & techniques for broadcast applications of granular pesticides with air blast machines	Wooster, Ohio	No	
AEa1-22 (sup. AEa1-3)	Evaluation of devices for distribution and metering of pre-emergence herbicides on the soil and mixed with the soil in the surface layer	Ames, Iowa & Columbia,Mo.	Yes	3-D-2
AEa1-23 (sup. AEa1-3)	The development and evaluation of equipment for control of corn insects in the Midwest	Wooster, Ohio Ames, Iowa	Yes	3-C-1
AE-0-0-2 (DOD)	Equipment and techniques for applying herbicides to vegetation in Puerto Rico and Texas	Mayaguez,P.R. College Sta.,Tex.	Yes	3-I-1
A10-AE-5 (PL-480)	Application of air jets with a vortex to improve penetration of air-borne insecticide sprays into dense foliage of citrus trees	Israel	Yes	3-J-1
Charter	Physics of Fine Particles,Pioneering Research Lab.	Wooster, Ohio	Yes	3-A-1
AEa2	Planting & fertilizing equipment & practices Program leadership	Beltsville, Md.		
AEa2-4 (Rev.)	Equipment for applying liquid fertilizer	Beltsville, Md. E.Lansing, Mich.	No	
AEa2-5 (Rev.)	Laboratory studies of the performance characteristics of seeding & fertilizer dispensing devices & equip.	Beltsville,Md.	No	
AEa2-8 (sup.AEa2-1 rev.)	Equipment and practices for pasture and hay land establishment and maintenance	Beltsville, Md. Bushland, Tex. Athens, Ga.	Yes	2-B-1
AEa2-9	Development of equipment and techniques for cotton planting	Shafter, Calif. Lubbock, Tex.	Yes	2-C-3
AEa2-10(C)	Design and development of range seeding equipment for use with brush eradication equipment in the arid Southwest	Las Cruces, New Mexico	Yes	2-B-2
AEa2-11 (sup.AEa2-2)	Planting and fertilizing placement machinery for cultivated field crops & vegetable crops	Md.,Va.,Mich. Ariz.,Wash,Nev.	Yes	2-A-1 2-D-1

*Reporting Year for all projects concerned with cotton--July 1, 1964 to June 30, 1965.

Line Project Check List -- Reporting Year April 1, 1964 to March 31, 1965*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl.in Area & Sub-heading
AE00-1	Equipment and methods for decontamination of agricultural lands affected by radioactive fallout	Beltsville,Md.	Yes	2-E-1
AEa3	Tillage machinery investigations Program leadership	Beltsville,Md.		
AEa3-1 (Rev.)	Soil dynamics as a factor in tillage tool design	Auburn, Ala.	Yes	1-B-3 1-C-1
AEa3-2 (Rev.)	Basic studies of soil-working tools	Auburn, Ala.	Yes	1-D-1
AEa3-3 (Rev.)	Soil Compaction by machinery	Auburn, Ala.	Yes	1-B-3
AEa3-4 (Rev.)	Design and use of deep tillage implements	Auburn, Ala.	No	
AEa3-5 (Rev.)	Effect of design factors on traction and transport equipment performance	Auburn, Ala.	Yes	1-A-1
AEa3-6 (Rev.)	Development of tillage machinery that will reduce soil erosion and runoff	Ames, Iowa	Yes	1-F-1
AEa3-7 (Rev.)	Measurement and characterization of physical properties of soil as related to tillage implements and tractive effort	Auburn, Ala.	Yes	1-C-2
AEa3-8 (Rev.)	Mathematical relationships between forces and deformation in soil	Auburn, Ala.	Yes	1-E-1
AEa3-11	Equipment for transferring soil layers and improving surface soil characteristics	Stoneville, Miss.	Yes	1-B-2
A10-AE-2 (PL 480)	Tillage methods and implements for mountain farms***	Jerusalem,Israel	Yes	1-G-1
E15-AE-1 (PL-480)	Development of methods and equipment for breaking up cohesive clay soils into small clod sizes up to a deep depth	Bologna, Italy	Yes	1-G-2
AEb1	Farm housing Program leadership	Beltsville, Md.		
AEb1-2 (Rev.#2)	Experimental farmhouses	Athens, Ga. Beltsville, Md.	No	
AEb1-3	The effect of selected construction and heat distribution means on environment, livability and climatic response in an expansible farmhouse	Beltsville, Md.	Yes	8-C-2
AEb1-5	Optimum attic fan arrangements for modern rural dwellings	Athens, Ga.	Yes	8-C-1
AEb1-6	Effect of window and floor coverings on thermal environment in modern rural dwellings	Athens, Ga.	Yes	8-A-1
AEb1-7	Effect of window and floor coverings on noise environment in modern rural dwellings	Athens, Ga.	Yes	8-A-2
AEb1-8	Rural dwelling plan development**	Beltsville, Md.	Yes	8-A-3,8-D
AEb1-9	Planning guides for housing units for senior citizens**	Beltsville, Md.	Yes	8-D
AEb1-10	Planning guides for housing units for migratory and seasonal farm workers**	Beltsville, Md.	Yes	8-D
AEb2	Livestock shelters Program leadership	Beltsville, Md.		
AEb2-1 (Rev.2)	Determination of environmental design criteria for poultry house design	Beltsville, Md.	Yes	9-D-1
AEb2-2 (Rev)	Environmental factors influencing development, production & health of dairy & beef animals under controlled conditions	Columbia, Mo.	Yes	9-A-2
AEb2-3 (Rev.)	Investigation of environmental factors influencing development, production & health of animals in warm climates***	Davis, and El Centro,Calif.	Yes	9-B-1 9-C-1,9C2 4, 5
AEb2-5	Reducing time and labor in caring for dairy animals through improved layout of buildings & yards, & the selection and adaptation of equipment***	Davis, Calif.	Yes	9-A-1
AEb2-7 (Rev)	Livestock shelters for southeast	Tifton, Ga.	Yes	9-C-3

* Reporting year for all projects concerned with cotton--July 1, 1964 to June 30, 1965
** Initiated during reporting year
*** Discontinued during reporting year

Line Project Check List -- Reporting Year April 1, 1964 to March 31, 1965*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-heading
AEb2-8	Evaluation & development of equipment & procedures for reducing chemical hazards associated with the control of livestock insects	Kerrville,Tex.	Yes	9-G
AEb2-9	Evaluation of radiant fluxes from the sky, ground & surroundings, & their influence on the radiant environment of livestock	Davis, Calif. Columbia,Mo.	Yes	9-F
AEb2-10	Use of models for analyzing farmstead layouts	St.Paul, Minn.	Yes	10-E-1
AEb2-11	Time standards for farmstead work elements	St. Paul, Minn.	Yes	10-E-2
AEb2-12	Principles of planning farmstead layouts to reduce labor required in production of livestock and poultry**	Davis, Calif.	Yes	9-A-1
AEb2-13	Development of prototype environmental cabinet for poultry disease research	Athens, Ga.	Yes	9-D-2
AEb2-14	Design and layout criteria for labor-saving structures and related equipment for feeding cattle**	Davis, Calif.	No	
AEb2-15	Environmental stress zones as criteria for design of heating, ventilating & air-conditioning equipment for turkey production	St.Paul, Minn.	Yes	9-D-5
AEb2-16	Bioengineering studies relating to environmental factors & physiological responses of swine with emphasis on humidity & high temperatures**	Davis, Calif.	Yes	9-C-1,5
AEb2-17	Bioengineering studies of factors affecting the relationship of environment & growth & feed utilization of beef cattle**	El Centro,Calif.	Yes	9-B-1
AEb2-18	Development & test of shelters & related equipment for protecting farm animals from hot, dry climates**	Davis, & El Centro, Calif.	Yes	9-B-1, C-2,C-4, 6
AEb3	Storages & related equipment for farm products Program leadership	Beltsville, Md.		
AEb3-10 (Rev)	Studies of basic factors in design & operation of silos	Beltsville, Md.	Yes	7-A-1,2
AEb3-11 (Rev)	Development of improved methods, equipment and structures for making, storing & feeding silage in southeast	Athens, Ga.	Yes	7-A-1
AEb3-12	Farm storage of high moisture grain	Ames, Iowa	Yes	7-A-5
AEb3-13	Silage and other forage density measurement with radioactive isotopes	Beltsville, Md.	Yes	7-A-1
AEb3-14 (Rev)	Pressures of wheat & soybeans on bin walls, floors and structural members	Ames, Iowa	No	
AEb3-15	Structures and related equipment for control of plant environment	Beltsville, Md.	Yes	7-B-1,2
AEb4	Farm building plan exchange & information Program leadership	Beltsville, Md.		
AEb4-5 (Rev)	Farmhouse plans and information***	Beltsville, Md.	Yes	8-A-3,8-D
AEb4-6 (Rev)	Farm service building plans and information***	Beltsville, Md.	Yes	7-C,9-A-3 9-B-3,10C-3 9-D-6,9-C-7
AEb5	Materials & construction methods for farm buildings Program leadership	Beltsville, Md.		
AEb5-5	Development & evaluation of Portland cement-sand sandwich panels	Beltsville, Md. Blacksburg, Va.	No	
AEb5-6	Incorporation & application of hyperbolic paraboloid (HP) theory to the structural use of sheet materials in farm structure roof design	Beltsville, Md.	Yes	10-C-1
AEb5-7	Evaluation of rotational resistance of nailed joints to be used in farm structures	Blacksburg, Va.	Yes	10-C-2

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AEb5-8	Floor deck and slab studies (primarily for rural dwellings)	Beltsville, Md.	Yes	8-B-1
AEb5-9	Influence of housing structures & equipment on air-saculitis & condemnations of broilers	State College, Miss.	Yes	9-D-3,4
AEb5-10	Investigations of the nature and magnitude of wind forces on farm structures**	Blacksburg, Va.	Yes	10-A
AEb5-11	Building foundations in expansive clay soils**	Starkville,Miss.	Yes	8-B-3
AEb5-12	Farm service building plan development**	Beltsville, Md.	Yes	10-C-3,7-C 9-A-3,9-B-3, 9-C-7,9-D-6
AEb5-13	Prototype low-cost house construction**	Charlestown,W.Va.	Yes	8-B-2,8-C-2
AEb5-14	Safety features for rural structures	Beltsville, Md.	Yes	10-B
AEb6	Farmstead water supply & wastes disposal Program leadership	Beltsville, Md.		
AEb6-2 (Rev)	Farmstead water requirements	College Pk.,Md.	Yes	10-D-1
AEb6-3	Characteristics of farm animal manures affecting design of disposal facilities	College Pk.,Md.	Yes	10-D-3
AEb6-4	Farm animal manure disposal lagoons	College Pk.Md.	Yes	10-D-3
AEb6-5	Pesticide pollution of farmstead water supplies	Beltsville, Md. Watkinsville, Ga.	Yes	10-D-2
A7-AE-3 (PL-480)	Studies on use of pure strains of algae and mixed algae-protozoa and algae-bacteria cultures in sewage treatment**	Baroda, India	Yes	10-D-4
AEc1	Cotton ginning investigations Program leadership	Beltsville, Md.		
AEc1-14	Measuring elements of fiber quality as affected by ginning & associated operations	Stoneville, Miss Mesilla Pk., N.M. Clemson, S. C.	Yes	6-C-1 6-F-2
AEc1-15	Moisture contents of cotton for optimum gin house operation	Stoneville, Miss. Clemson, S.C.	Yes	6-B-1
AEc1-24	Fundamental mechanisms of nep formation in cotton	Mesilla Pk.,N.M.	Yes	6-F-2
AEc1-28	Reducing the degrading effects of weathering in the field & the action of insects & microorganisms on ginned cotton fiber & seed	Clemson, S.C.	Yes	6-C-1
AEc1-31	Cotton ginning efficiency and cost	Stoneville, Miss. Clemson, S.C. Mesilla Pk.,N.M.	Yes	6-F-1
AEc1-32	Development of alternative seed cotton cleaning devices & methods based on a thorough evaluation of present equipment	Stoneville, Miss. Clemson, S.C.	Yes	6-C-1 6-I-1
AEc1-33	Improvement & evaluation of equipment for cleaning lint cotton	Stoneville,Miss.	Yes	6-G-1
AEc1-34	Improving cotton ginning performance through cotton quality evaluations and their relationships to ginning and associated operations	Mesilla Park, N.M.	Yes	6-F-3
AEc1-35	Improving extra long staple cotton ginning means and methods	Mesilla Park, N.M.	Yes	6-E-2
AEc1-36	Roller gin adjustment for optimum performance	Mesilla Pk., N.M.	Yes	6-E-2
AEc1-37	Measurement of raw cotton length for cotton ginning evaluation	Stoneville, Miss. Mesilla Pk., N.M. Clemson, S.C.	Yes	6-F-2
AEc1-38	Gin stand research and development	Stoneville, Miss.	Yes	6-E-1 6-I-1
AEc1-39	Materials handling & collection at cotton gins	Stoneville, Miss. Mesilla Pk., N.M. Clemson, S.C.	Yes	6-A-1 6-D-1 6-J-1
AEc1-40	Effects of production & harvesting methods and practices on cotton ginning and fiber quality**	Stoneville, Miss. Mesilla Pk., N.M. Clemson, S.C.	Yes	6-F-3

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AEc1-41	Cotton bale packaging improvement**	Stoneville, Miss. Clemson, S.C.	Yes	6-H-1
AEc1-42	Relationship of temperature, moisture, impact, & tensile stresses during ginning to fiber strength, length distribution, and yarn quality**	Stoneville, Miss. Mesilla Pk., N.M. Clemson, S.C.	Yes	6-F-2
AEc2	Long vegetable fiber engineering investigations Program leadership	Beltsville, Md.		
AEc2-2 (Rev)	Improving processes & techniques for cleaning ramie ribbons	Belle Glade, Fla.	No.	
AEc2-7 (Rev.)	Development harvesting & farm handling equipment for bamboo	Belle Glade, Fla.	Yes	4-F-1
AEc2-8 (Rev.)	Sansevieria harvesting, defibering, & fiber conditioning machinery & methods	Belle Glade,Fla.	Yes	4-F-2
AEc2-9 (Rev.)	Development of improved harvesting & processing machinery & methods for the production of kenaf and other jute like fibers	Belle Glade, Fla.	Yes	4-F-3
AEc3	Equipment for harvesting & farm handling of fruits and vegetables Program leadership	Beltsville, Md.		
AEc3-13 (Rev.)	Equipment & methods for handling & harvesting Concord grapes	E. Lansing,Mich.	Yes	4-C-1
AEc3-14 (Rev.)	The effect of tillage & cultural practices on mechanized potato harvesting	E.Grand Forks, Minn.	Yes	1-B-1
AEc3-20	Equipment & methods for mech. harvesting cling-stone & freestone peaches & apricots***	Davis, Calif.	Yes	4-C-2
AEc3-21	Mechanical injury of potatoes-evaluation, causes and prevention	E. Grand Forks, Minn.	Yes	4-H-1
AEc3-22	Equipment & methods for thinning peaches & apples mechanically***	E.Lansing,Mich.	No	
AEc3-24	Equip. & methods for harvesting dates mechanically	Davis, Calif.	Yes	4-C-3
AEc3-25	Equipment and methods for harvesting and field handling citrus fruit	Lake Alfred,Fla. Davis, Calif.	Yes	4-A-1
AEc3-26	Mechanical aids and harvesting equipment & methods for picking apples for the fresh market	Wenatchee, Wash. E.Lansing, Mich.	Yes	4-C-4 4-C-5
AEc3-27	Mechanized picking of apples and pears for processing outlets.	Wenatchee, Wash. E.Lansing, Mich.	Yes	4-C-6
AEc3-28	Development of equipment and methods for harvesting of apples & pears from trees of different sizes, shapes and planting distances.	Wenatchee, Wash. E.Lansing, Mich.	Yes	4-C-5
AEc3-29	Development of continuous-type self-propelled machine for harvesting cultivated blueberries	E. Lansing, Mich.	Yes	4-C-7
AEc3-30	Equipment and methods for maintaining quality of cherries during mechanical harvesting & handling	E. Lansing, Mich.	Yes	4-C-8
AEc3-31	Methods and equipment for harvesting prunes grown in the Coastal Region of California	Davis, Calif.	Yes	4-C-9
AEc3-32	Bark damage to fruit trees resulting from mechanical shakers	Davis, Calif. Lake Alfred,Fla. E.Lansing,Mich.	Yes	4-C-10
AEc3-33	Development of methods and equipment for multirow harvest of potatoes	E.Gr.Forks,Minn.	Yes	4-H-2
AEc3-34	The development of equipment for application of dust to seed potatoes	E.Gr.Forks,Minn.	Yes	4-H-3
AEc3-35	The development of equipment and methods for harvesting coffee**	Honolulu and Kona, Hawaii	Yes-	4-C-11
AEc4-	Farm seed cleaning & handling Program leadership	Beltsville, Md.		
AEc4-4 (Rev)	Seed cleaning research applied to specific problem mixtures	Corvallis, Ore.	Yes	5-A-1
AEc4-7	Improved techniques for harvesting seed crops***	Corvallis, Ore.	No	
AEc4-8(Rev.)	Development of a centrifugal-pneumatic seed separator	Corvallis, Ore.	Yes	5-A-2

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AEc4-10	Optimum moisture content for seed harvesting***	Corvallis,Ore.	Yes	4-E-1
AEc4-11	Modification of seed-length separators***	Corvallis,Ore.	Yes	5-A-3
AEc4-12	Development of vibratory feeders for seeds***	Corvallis, Ore.	No	
AEc4-13	Development of a high-speed scalper for seed crops	Corvallis, Ore.	No	
AEc4-14	Development of components for cutting, picking up, threshing, and cleaning field seed crops.**	Corvallis,Ore.	Yes	4-E-2
AEc5-	Equipment for mechanical cotton production Program leadership	Beltsville, Md.		
AEc5-4	Equipment & techniques for crop residue disposal in cotton production	Stoneville, Miss.	Yes	2-C-1
AEc5-5	Equipment & methods for optimum seedbed preparation for cotton	Stoneville, Miss. Shafter, Calif.	Yes	2-C-2 1-B-4
AEc5-6	Power requirements of cotton production implements	Stoneville, Miss. Shafter, Calif.	Yes	2-C-2
AEc5-7	Synthetic mulches for improving cotton stands	Stoneville, Miss. Lubbock, Tex.	No	
AEc5-8	Cooperative studies on the effects of production practices on the end use quality of cotton and cottonseed	Stoneville, Miss. Auburn, Ala. Lubbock, Tex. Shafter, Calif.	Yes	4-B-1 4-B-4
AEc5-9 (Rev.)	Evaluation and development of cotton harvesting machines	Stoneville, Miss. Lubbock, Tex. Shafter, Calif.	Yes	4-B-5 4-B-6 4-B-7
AEc5-10	Reduction of moisture added to seed cotton by spindle-type harvesters	Stoneville, Miss. Shafter, Calif.	No	
AEc5-11	Sources of trash in cotton harvesting	Auburn, Ala. Stoneville, Miss.	Yes	4-B-2
AEc5-12	Plant characteristics affecting the performance of mechanical cotton harvesters	Auburn, Ala. Stoneville, Miss.	Yes	4-B-3
AEc5-13	Field separation of immature cotton bolls from mature cotton	Lubbock, Tex.	Yes	4-B-7
AEc5-14	Field handling and storage of machine-harvested cotton	Lubbock, Tex. Stoneville, Miss.	Yes	4-B-8
AEc5-15(C)	Cottonseed germination and quality as affected by harvesting and ginning operations**	State College, Miss. Clemson, S.C. College Station, Tex.	No	
AEc6	Grain harvesting & conditioning Program leadership	Beltsville, Md.		
AEc6-10	Effects of heated air drying on grain quality***	Ames, Iowa	No	
AEc6-11	Moisture relations in grains as they affect drier design	Ames, Iowa	Yes	5-C-1
AEc6-12 (Rev.)	Studies of the drying zone in mechanical grain driers	Ames, Iowa	Yes	5-C-2
AEc6-14	Mechanical damage to corn during harvesting & handling	Ames, Iowa	Yes	5-C-3
AEc6-15	Permissible time for drying grain using unheated air	Ames, Iowa	Yes	5-C-4
AEc7	Specialized crop production & harvesting machinery Program leadership	Beltsville, Md.		
AEc7-8 (Rev)	Development & improvement of peanut diggers and shakers	Holland, Va.	Yes	4-G-4
AEc7-9 (Rev)	Development & improvement of tung harvesters & windrowers for optimum effectiveness & efficiency	Bogalusa, La.	Yes	4-G-2
AEc7-10 (Rev)	Development & improvement of equipment & methods of handling tung fruit to storage on farm and to processing mill	Bogalusa, La.	No.	
AEc7-11(Rev.)	Farm Processing of tung nuts	Bogalusa, La.	Yes	5-E-1
AEc7-13 (Rev.)	Development & improvement of peanut harvesting & field handling equipment	Holland, Va.	Yes	4-G-5

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AEc7-14 (Rev)	Development of improved harvesting, hulling & conveying equipment for castor beans and other oilseed crops	Stillwater, Okla.	Yes	4-G-1
AEc7-15	Development of a cutter, cleaner, loader type of sugarcane harvester***	Houma, La.	Yes	4-I-1
AEc7-16	Engineering studies of factors related to harvesting and farm processing Coastal bermudagrass	Tifton, Ga.	Yes	5-D-1 4-D-1
AEc7-17	Mechanical harvesting Burley tobacco	Lexington, Ky.	Yes	4-J-1
AEc7-18	Curing Burley tobacco	Lexington, Ky.	Yes	5-B-1
AEc7-19	Physical properties, forms, & treatments of forage	Beltsville, Md.	Yes	5-D-2 4-D-2
AEc7-20	Pruning of tung trees for facilitating the use of equipment in production and harvesting	Bogalusa, La.	Yes	4-G-3
AEc7-21	Determine the engineering requirements for artificially conditioning castor beans for effectively hulling & maintenance of quality in storage	Stillwater, Okla.	Yes	5-F-1
AEc7-22(C)	Mechanically removing tops & lead trash from sugarcane**	Baton Rouge, La.	Yes	4-I-2
AEc7-23	Gathering and cutting recumbent-type sugarcane from the row**	Belle Glade, Fla.	Yes	4-I-3
AEc7-24(C)	Equipment and methods for the farm curing and drying of Virginia-type peanuts**	Blacksburg, Va.	No	
AEc7-25	Equipment and methods for the farm curing and drying of peanuts**	Blacksburg, Va. Holland, Va.	No	
AEc7-26(C)	Determination of location, nature, & extent of losses & damage occurring in peanut harvesting and farm handling**	Tifton, Ga.	No	
S3-AE-2 (P1-480)	Investigations in mechanization of sugarcane	Brazil	Yes	4-I-4
AEd2	Automatic electric controls for farm equipment Program leadership	Beltsville, Md.		
AEd2-1 (Rev)	Development of electric & other labor-saving & honey-conditioning equipment for apiary operation in North Central states	Madison, Wis.	Yes	12-C
AEd2-2 (Rev)	Development of electric & other labor-saving & honey-conditioning equipment for apiary manipulation in S.W.	Tucson, Ariz.	Yes	12-C
AEd2-5 (Rev)	Automatic electric control systems and equipment for livestock production	Urbana, Ill.	Yes	12-A-B
AEd2-6	Electric equipment for removing & handling silage from horizontal silos	Pullman, Wash.	Yes	12-A
AEd3	Electric equipment for environmental modification & control in farm living & production Program leadership	Beltsville, Md.		
AEd3-3 (Rev)	Study of electrical heat pumping devices for agricultural application with solar supplementation for the airconditioning of farm homes and other farm buildings	Manhattan, Kan.	Yes	13-E-1,2
AEd3-5	Equipment systems for controlling light & temperature for turkey breeding stock***	Beltsville, Md.	No	
AEd3-7	Electric equipment for efficient hog production (including heat pump for cooling & heating hog houses)	Holland, Va.	Yes	13-B
AEd3-8	Design factors for electrically controlled air flow and ventilation equipment in broiler houses	Athens, Ga.	Yes	13-A
AEd3-9	Relation & control of carbon dioxide & light & their effects on plants in air supported plastic green houses	Pullman, Wash.	Yes	13-D-1

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AEd3-10	Development of electric equipment to provide environmental control for investigations of sub-circadian periodicity in poultry	Beltsville, Md.	Yes	13-A
AEd3-11	Development of design criteria for lighting and other electrical equipment & controls for plant-growth environments	Beltsville, Md.	Yes	13-D-2
AEd3-12	Engineering design and development of equipment & controls to modify plant environment by the application of carbonated water to supply supplemental carbon dioxide**	Manhattan, Kan.	Yes	13-D-1
AEd4	Application of electromagnetic radiation to plants, animals, & their products & to insects & soils Program leadership	Beltsville, Md.		
AEd4-1 (Rev)	Development of equipment for attracting and/or destroying economic insects with electric energy in North Central states	Lafayette, Ind. Ames, Iowa	Yes	11-A-1,2 11-B
AEd4-2 (Rev)	Use of radiofrequency energy for insect control and conditioning of farm products	Lincoln, Neb.	Yes	11-D-1,2
AEd4-3 (Rev)	Development of electrical equipment for attracting and/or destroying economic insects in the S.W. states	College Sta., Tex.	Yes	11-A-3 11-B
AEd4-4 (Rev)	Development of electromagnetic radiation equipment for seed & plant product treatment	Knoxville, Tenn. Pullman, Wash.	Yes	11-D-1,3, 4,5,6
AEd4-5	Development of equipment for attracting, repelling and/or destroying economic insects with certain physical stimuli in southeastern states	Blacksburg, Va. Oxford, N.C. Lexington, Ky.	Yes	11-A-4
AEd4-6	Evaluation & development of equipment & physical methods for control of flies & other livestock pests	Beltsville, Md.	Yes	11-C
AEd4-7	The response and physiological effects of light on the boll weevil	State College, Miss.	Yes	11-A-3
AEd4-8(C)	Insect response to sound stimuli**	Blacksburg, Va.	No	
AEd4-9(C)	Electric insect traps for control of tobacco insects**	Oxford, N.C. Lexington, Ky. Blacksburg, Va.& South Carolina	Yes	11-A-4
AEd4-10	Development of equipment for attracting and/or destroying economic insects with electric energy in the Pacific Coast states**	Riverside,Calif.	Yes	11-A-1
AE-ENT-1(C)	Investigation of insect attraction and communication possibilities in the infrared spectral region**	Beltsville, Md.	No	
AEd5	Farm electric equipment performance & requirements & farm electric energy distribution Program leadership	Beltsville, Md.		
AEd5-1 (Rev)	Determination of electric demand characteristics of farm equipment	Ames, Iowa	Yes	14-A
AEd5-3	Electric milk cooling & handling equipment performance requirements	Beltsville, Md.	Yes	13-C
AEd5-4 (Rev)	Performance tests of unloaders for vertical silos	St. Paul, Minn.	Yes	12-A
AEd5-5	The use of 480 volts for distribution & use of electric energy for farm use***	St. Paul, Minn.	No	
AEd5-6	Evaluation of electric systems for soil warming	Lafayette, Ind.	Yes	13-D-3
AEd5-7	Development of requirements & electric equipment for conditioning potatoes for processing**	E.Gr.Forks,Minn. St. Paul, Minn.	Yes	13-D-4

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AEd6	Development of technical instruments & measurement techniques for farm production & related electrification research			
	Program leadership	Beltsville, Md.		
AEd6-2	Evaluation of lamps producing ultraviolet and visible electromagnetic irradiance (0.2 to 1.0 micron wavelength)**	Beltsville, Md.	Yes	14-B
A17-AE-1 (PL 480)	Development of solar powered equipment for operating a small irrigation pump	Lahore, Pakistan	No	

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